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New Challenges for a New Era

Progress Through Innovation, Education and Research in North Carolina

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Final Report
of the
Governor's Task Force on Science and Technology

VOLUME IV
PUBLIC EDUCATION AND THE TECHNOLOGICAL CHALLENGE

N.C. Board of Science and Technology
Office of the Governor
Raleigh, North Carolina
January, 1984

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NEW CHALLENGES FOR A NEW ERA

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ACKNOWLEDGEMENTS

Task Force members wish to express their appreciation to the hundreds of persons who contributed to this study, particularly associate committee members, regional forum participants, and state government personnel.

The Task Force was staffed by four persons who contributed to all facets of Task Force activities and drafted the final report. Tom Rudin was the principal author of Volume I; Kirsten Nyrop, Volume II; Shannon St. John, Volume III; and Sanford Shugart, Volume IV.

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TITLES OF EACH VOLUME

Volume I - A Vision of Opportunity

Volume II - Economic Revitalization Through Technological Innovation

Volume III - Research and Higher Education: Building a Foundation for Education

Volume IV - Public Education and the Technological Challenge

Supplemental reports have been prepared by the Task Force's Committees on Agriculture and Forestry, N.C. and the World Community, and Science, Technology and Human Values.

All four volumes and copies of the supplemental reports can be obtained upon request from:

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(919) 733-6500

PREFACE

Volume IV of the final report of the Governor's Task Force on Science and Technology is the culmination of several years of work and discussion directed toward improving K-12 science and mathematics education in North Carolina.

The report and recommendations are organized into four broad categories: improving the supply and quality of teachers, improving the enrollment and performance of students, improving the curriculum and instructional resources, and fostering innovation and consensus for improving education.

Some first steps toward improving science and mathematics instruction have already been initiated in North Carolina. What is needed now is a long-range, comprehensive strategy to assure excellence in science and mathematics in our state. The recommendations in this report provide such a strategy. For this reason, they should not be treated independently as a "shopping list" of options. Rather they should be molded into a complete strategy for moving toward excellence in science and mathematics education over the next several years.

This report represents the ideas and labor of many citizens -- teachers, school leaders, scientists, community leaders, higher educators, business and industrial leaders, parents, and others. Though our perspectives vary, we share a strong belief that improving education in North Carolina, especially in science and mathematics, is crucial to the future of our state. We commend this report to all who read it as a blueprint for improving science and mathematics education in North Carolina's public schools.

The Committee on Elementary and Secondary Education wishes to thank Sanford Shugart for his staff support.

Committee Members

Dr. William B. DeLauder, Co-Chairman, N.C. A&T State University, Greensboro
Mrs. Jessie Rae Scott, Co-Chairman, American Cancer Society, Haw River
Dr. E. Maynard Adams, University of North Carolina at Chapel Hill
Ms. Flonnie Anderson, Career Center, Winston-Salem
Dr. Delma Blinson, Superintendent, Greenville City Schools, Greenville
Dr. William Byrd, East Carolina University, Greenville
Dr. Larry Clark, North Carolina State University, Raleigh
Mr. J. Herbert Coman, Sr., Beacon Corporation, Swannanoa
Mrs. Nancy Evans, D.H. Conley High School, Greenville
Ms. Sarah Hamilton, North Carolina School of Science and Mathematics, Durham
Mrs. Barbara Harris, Piedmont Technical College, Oxford
Mrs. Betty Ann Knudsen, Wake County Commissioners, Raleigh
Mrs. Mary Sue Noe, Carteret County Commissioners, Morehead City
Ms. Annie Puett, East Mecklenburg High School, Charlotte
Dr. Robert Williams, N.C. State University, Raleigh

Associates

Dr. Robert Jones, N.C. Department of Public Instruction, Raleigh
Mrs. Jean Joyner, N.C. Department of Public Instruction, Raleigh
Dr. Paul Taylor, N.C. Department of Public Instruction, Raleigh

GOVERNOR'S TASK FORCE ON SCIENCE AND TECHNOLOGY

*George P. Williams, Jr., Wake Forest University, Winston-Salem, Chairman
E. Maynard Adams, University of North Carolina at Chapel Hill
Flonnie Anderson, Career Center, Winston-Salem
+Lawrence Blake, N.C. Department of Community Colleges, Raleigh
T.C. Blalock, N.C. Tobacco Growers Association, Raleigh
David Burkhalter, Belk Stores Services, Charlotte
James Herbert Coman, Sr., Beacon Corporation, Swannanoa
+Ruth Cook, N.C. Utilities Commission, Raleigh
+Sexton Dale, North Carolina AFL-CIO, Morganton
*John DaVanzo, East Carolina University, Greenville
+Raymond Dawson, University of North Carolina General Administration, Chapel Hill
*William DeLauder, N.C. A&T State University, Greensboro
James Edmundson, University of North Carolina at Wilmington
*Nicholas Gillham, Duke University, Durham
+Leon Golberg, Duke University Medical Center, Durham
*Carl W. Gottschalk, University of North Carolina at Chapel Hill
Herman Grossman, Duke University, Durham
Walter Hannen, Citizens National Bank, Winston-Salem
Barbara Harris, Piedmont Technical College, Oxford
John Henley, N.C. Association of Independent Colleges and Universities, Raleigh
Robert L. Hill, Duke University Medical Center, Durham
E. Walton Jones, University of North Carolina General Administration, Chapel Hill
Robert Jordan, North Carolina State Senate, Mt. Gilead
*Betty Ann Knudsen, Wake County Board of Commissioners, Raleigh
Robert E. Lee, United Rubber Workers, Fayetteville
*Quentin W. Lindsey, Governor's Office, Raleigh
Thomas V. Long, II, Technology 2000, Chapel Hill
*Jerome Miksche, N.C. State University, Raleigh
Mary Sue Noe, Carteret County Board of Commissioners, Morehead City
*Jane S. Patterson, Secretary, Department of Administration, Raleigh
*Colin Pitt, Research Triangle Institute, Research Triangle Park
*Thomas E. Powell, III, M.D., Carolina Biological Supply Company, Burlington
*Jessie Rae Scott, American Cancer Society, Haw River
Harold Ray Thomas, DuPont Company, Kinston
*William F. Troxler, Troxler Electronic Labs, Inc., Research Triangle Park
Phail Wynn, Jr., Durham Technical Institute, Durham

* Member, N.C. Board of Science and Technology
+ No longer a Task Force member

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PUBLIC EDUCATION AND THE TECHNOLOGICAL CHALLENGE

INTRODUCTION

The public schools of our state and nation face a tremendous challenge. Numerous reports, commissions, and task forces have echoed this call for years. What must be understood now, however, is that this challenge comes not so much from some internal failure of the school system as from profound, sweeping changes in the society which our schools serve.

The engine of many of these sweeping social and economic changes -- which amount to nothing less than a transformation of society -- is science and technology. Advances in science and technology are affecting every area of our lives -- our jobs, the economy, our environment, communications, recreation, politics, family structures, values -- in short, our whole quality of life. This flood of change, for good or ill, cannot be averted, but it can be harnessed and guided for the benefit of society if we set out to do so deliberately.

Education is the central method for harnessing the power and promise of science and technology to benefit all citizens. In recent years, however, public support for education has eroded. The share of the state budget earmarked for elementary and secondary education, for example, has declined from 60 percent to 40 percent over the past 20 years.

The overriding premise of this report is that the state has a constitutional requirement to provide a general and uniform system of education, and a further obligation to ensure the highest quality education for every student across North Carolina. A substantial infusion of new funds, some reallocation of existing monies, and the implementation of new and innovative education programs are necessary to meet this obligation. The General Assembly, the State Board of Education, and local school systems must reaffirm their commitment to this goal with short-term and long-term investments in elementary and secondary education.

New Skills for a New Age

As technology continues to accelerate, its impact on our economy is becoming clear. According to some estimates, new technologies will account for as many as 10 times the number of new jobs (i.e. in occupations which do not now exist) as all other industries in the next decade. Some of these new jobs will require a high level of technical sophistication for workers to creatively apply these new technologies. However, many of the new occupations will involve routine, uncreative operation of sophisticated devices. Meanwhile, jobs in traditional industries are being transformed by advances in information processing, robotics, communications, lasers, fiber optics and biotechnology. Our success in this transformation will depend on our ability to provide skilled workers -- laborers, technicians, managers, scientists and engineers, service and sales people, and support personnel. This view was recently confirmed here in North Carolina by a chief executive officer of a

Japanese microelectronics firm who claimed that the relocation of a $40 million plant to our state had hinged on the quality of our education and training for his potential employees.

Many of the new skills demanded by technological growth will be technical, such as in computers, electronics, science, and mathematics. Other more generic skills in problem solving, communication, analysis, and functioning in complex organizations are also needed.

Furthermore, even those citizens who are not employed in the more sophisticated occupations will benefit from improved education in science and mathematics through more effective consumer decisions, enhanced citizenship and recreation.

Informed Participation in a Technological Society

While the promise of scientific and technological development is significant, science and technology do not provide simple "fixes" for many of our problems. Frequently, in fact, they present a number of difficult and complex choices in themselves.

If we are to harness and guide science and technology with justice and integrity, these choices will require full and informed citizen participation. Intelligent public decisions on these matters cannot be made without technical expertise. In short, guiding the changes will require that our educational institutions provide all North Carolinians with a new higher level of general scientific and technological literacy, access to a strong pool of knowledge and expertise for decision making, and careful long-range planning to accomplish our goals. These are new and difficult challenges for our educational systems, but they must be effectively addressed.

In addition, the potential impact of science and technology requires that we deliberately cultivate wisdom as well as expertise in the decisions we make. Such a demand translates into a need to nurture the arts and humanities, and relate them to contemporary issues; to cultivate consensus and tolerance on value choices through reflection and public debate; and to seek sensitivity to the religious and cultural communities which can inform our efforts to secure a higher quality of life in the midst of technological change.

Technological Innovation in the Schools

As the rate of scientific advance accelerates, we must learn to master the use of new technologies to achieve our social and economic goals. This process of technological innovation is dependent on both the quality of our research and development enterprises and the ways in which we organize ourselves to take advantage of new technologies. This organization process is called institutional innovation.

This need to adapt our existing institutions to capitalize on new technologies imposes significant demands on all of our institutions, and especially our educational systems.

In education, for example, new developments such as microcomputers, videodiscs, and interactive telecommunications offer new organizational challenges. We may, for instance, enhance our schools by simply adding microcomputer literacy and programming courses to the curricula. Or we may put computers in a number of classrooms to be used as electronic blackboards and worksheets. However, tapping the full educational potential of the microcomputer may require that we attempt some truly innovative changes in the way schools are organized.

Many have predicted radical changes in education due to new technologies over the years -- teaching machines, television, and videotape were all expected to revolutionize how we learn and even make classroom teachers obsolete. Yet, through each new trend the schools have remained remarkably unchanged.

The most significant challenge faced by our public schools may be the need to become more innovative in the face of technological change. We will argue in this report that planned, sensible, innovative changes in our schools are demanded by our evolving society. We call for a careful reexamination of the way schools are organized, led, staffed, financed, and supported. The curricula, the availability and use of instructional resources, teaching methods, educational technology, expectations, extracurricular activities, even the missions of our schools need to be reviewed and adjusted as society changes.

This demand to master technological innovation is being felt and responded to in all of our social institutions -- in business and industry, government, health care, law enforcement, agriculture, etc. If we are timid and attempt to insulate our schools from change, they may become archaic and unproductive organizations leading to a further deterioration of public confidence and support. If, however, our schools become innovative, proactive institutions in the face of change, they will be recognized as the key to our success as a technological society.

Educational Goals and Institutional Challenges

The new demands of our rapidly changing technological society strike at the very heart of the mission of our public schools. The citizens of North Carolina have clearly recognized the central role which education will play as we move toward the 21st century. It is important to note that respondents to the N.C. 2000 survey listed quality education as the state's top priority for the years to come. Similarly, the recent report of the Education Commission of the States National Task Force on Education for Economic Growth, chaired by Governor James B. Hunt, Jr. recognized that:

> "our future success as a nation -- our national defense, our social stability and well-being and our national prosperity -- will depend on our ability to improve education and training for millions of individual citizens..."

The rate of technological change throughout society has made the need to achieve our fundamental educational goals more crucial than ever before. Yet even as the importance of achieving these goals is becoming widely acknowledged so are the dimensions of the challenges we face.

North Carolina's system of public elementary and secondary education serves some 1.1 million students in 143 local school systems. With a total budget of $2.24 billion, of which 1.46 billion, or 65.2 percent, is provided by the state, public education in grades K-12 accounts for a substantial portion of public expenditures in the state. Approximately 92 percent of the state's K-12 expenditures are alloted to salaries and benefits for public school employees, including more than 55,000 teachers and over 4,100 administrators.

In contrast to many other states, North Carolina's State Department of Public Instruction plays a central role in many educational policies and programs. This places the state in a strong position to mobilize a concerted effort with state leadership and local cooperation for confronting the many challenges faced by our public schools.

Important challenges which our schools face in response to technological change include:

- o Basic Literacy. Nearly 800,000 North Carolinians have less than an eighth grade education.

- o Public School Facilities. The Governor's Task Force on School Facilities recently reported that public school buildings were frequently in critical need of improvement. According to their survey, some $1.8 billion in school building improvements will be required over the next six years.

- o High School Dropouts. Nearly 25,000 students drop out of North Carolina's high schools each year. A recent Task Force highlighted the importance of addressing this issue as we move into a technological era.

- o Vocational Education. As technology continues to transform the workplace, there are significant implications for the curriculum, organization and finance of vocational education.

- o Public School Finance. The recent Governor's Task Force on Public School Finance highlighted a number of critical issues faced in funding our public schools. Perhaps of most immediate concern is the use of simplistic enrollment-driven formulas which are sensitive neither to inelastic program costs nor the effects of projected enrollment declines.

- o Parents and Education. No innovative program, no amount of investment, no level of excellence in instruction can long overcome a home environment which is unsupportive of a pupil's learning. Signifi-

> cant improvement in our educational achievements will require that parents become more active partners in the education of their children.

These and many other problems challenge the effectiveness of our public schools. Because of the significance of the technological changes taking place in our society, however, the Task Force has focused primarily on science and mathematics education. Particular problems are faced in these crucial instructional programs, as this report will indicate. Our call to action to address these problems does not ignore other educational issues. Rather, a comprehensive strategy for addressing all of these crucial issues is needed. It is our firm conviction, however, that the strategy we present for improving science and mathematics education should be a central component of North Carolina's efforts for improving public education. Technological change -- in our economy, our homes, on our farms, and in public life -- demands this response.

The Underlying Challenge: Consensus and Commitment

Underlying each of these difficult issues is a more fundamental challenge. The report of the National Task Force on Education for Economic Growth astutely focused on this most difficult challenge:

> Our greatest overall educational deficiency in the United States...is our absence of clear, compelling and widely agreed upon goals for improving educational performance.

During the past two decades, a variety of new demands and expectations have been placed on our public schools. Often this has been done with little understanding of their effects on the central mission of schooling and little commitment of the resources -- time, money, and personnel -- necessary for meeting these new demands. Our schools have been asked to assure the physical and emotional health of all students, to desegregate a society whose housing and employment patterns made this extremely difficult and expensive, to provide an endless variety of programs for children with special needs, to provide adequate nutrition for many underprivileged pupils, to handle behavior problems which our legal system and parents could not remedy, to cope with an endless stream of regulations and their attendant paperwork, to provide adequate facilities and supervision to entertain whole communities, and to do all of this with a shrinking share of the state's resources. This is not to suggest that these demands have been inappropriate or nonessential. However, as the schools have struggled to meet the needs of a growing diversity of students, measures of their educational outcomes have been discouraging.

This combination of increased expectations and over-extended resources has led to an erosion of public confidence in and support for our schools. Add to this the alienating effects of increased centralization and bureaucratization of the schools, their general isolation from other components of the community, and politicization of educational issues, and it is no wonder we have reached a point of crisis in confidence in our public school system.

Yet, we are now entering an age when the demands placed on public education will be even more severe and their effectiveness even more critical to the success of our society.

It is clear, then, that our greatest challenge is to rebuild public consensus on the aims of education and the role of public schools, and to recommit ourselves to making the tough choices and necessary investments to make our schools outstanding. Without this consensus and commitment, none of the strategies and programs proposed by this Task Force or any other group are likely to succeed.

We are fortunate in North Carolina to have maintained standards of educational excellence which are envied by many other states. Yet, the challenges we face are nonetheless imposing. We must begin at once to build the consensus, support and confidence in our public schools which will enable us to affect the improvements which technological change demands. To do this, we believe an aggressive strategy must be pursued which includes clearly defined roles for both the state and local communities; it must address both short- and long-term objectives which are measurable; it must specify the significant investments necessary to achieve our goals; it must spell out specific actions that must be taken now and in the near future; and, most importantly, it must effectively address the fundamental challenge of creating the political consensus and commitment for making the sweeping changes which are necessary if real improvements are to be achieved.

The remainder of this report provides such a strategy for improvements necessary in science and mathematics education as well as some more general issues which effect all educational areas. We urge the careful consideration and bold implementation of this strategy. In addition, we encourage the leaders of this state and in each local community to develop and implement strategies to strengthen our K-12 educational programs in all areas where needed.

Chapter One

THE ROLE OF SCIENCE AND MATHEMATICS EDUCATION

While the impact of technological change on society has implications for all of our educational programs, the challenge is most immediate in the areas of science and mathematics education. The quality of science and mathematics education is crucial to our efforts to harness science and technology for the health and prosperity of society. The *N.C. 2000* report highlighted this issue:

> North Carolina's ability to utilize advances in science and technology to improve productivity, to stimulate economic development, and to enhance the quality of life for the state's citizens will depend...on ensuring scientific and technological literacy in the general population....A strong emphasis on more math and science instruction for *all* students is necessary.

Science and mathematics education will play a particularly important role in the coming years for three reasons. The first is the rapid expansion of high-technology industries. North Carolina has recently experienced great success in attracting and nurturing the growth of new technology industries. A key component in this success is the availability of a technically-trained workforce. Much of our success can be attributed to our outstanding community college and university systems. However, if we are to continue to compete successfully with other states and regions for these industries, and the jobs they create, strengthening the quality of science and mathematics programs throughout North Carolina in grades K-12 must become a statewide priority.

Nevertheless, the total number of high-technology jobs created will not ensure employment for everyone. Therefore, the second and more compelling argument for strengthening K-12 science and mathematics education is the significant impact of technical advances on traditional industries and work roles. In North Carolina, this impact is already being felt in industries such as textiles, agriculture, furniture manufacturing, banking and commerce. For these traditional mainstays of the state's economy to remain healthy and continue to grow, the technological literacy of the general workforce must be raised. The entire workforce -- from the most junior millworker to the senior managing director -- will have to rapidly adapt to new technologies and use these technologies for maximum productivity.

Third, as mentioned earlier, it is essential that science and mathematics education be strengthened if the impact of scientific and technological change on society is to be beneficial to all of our citizens. Scientific and technological literacy is crucial to our state if we are to make the best public and political judgments regarding the issues raised by this technological transformation, if we are to sustain our investment in basic research and development in the state, and if we are to assure every citizen of the right to full participation in a technological society.

Scientists and Engineers

As discussed in Volume III of this report, the growth in new technologies has put a considerable strain on our scientific and engineering manpower. According to some estimates, for instance, the demand for engineers may grow by some 40 percent in the next decade.

Whether we are able to fill this need will depend largely on the pool of adequately prepared high school graduates who can be recruited into science and engineering programs in our colleges and universities. We must increase the numbers of these students. Furthermore, as the number of students in our high schools continues to decline throughout this decade, the proportion of those preparing to enter college degree programs in science and engineering will have to increase.

However, present trends in both high school enrollment and performance in science and mathematics will lead to a deteriorating pool of talent from which colleges and universities can recruit. Already remedial courses in mathematics are common in our leading senior institutions. Nationwide, the number of students enrolled in remedial mathematics courses in colleges and universities has increased by 72 percent since 1970. Closer to home, nearly 600 freshmen were enrolled in remedial mathematics at North Carolina State University during the past year.

Meanwhile, enrollment in physical science and mathematics courses in North Carolina's high schools has declined steadily in recent years. While this trend seems to have leveled off in the last two years, there is clearly a need to increase the number of students--particularly females and minorities--in high school physical science and mathematics courses and to ensure that they are adequately prepared to enter degree programs in science and engineering upon graduation.

Technicians and Skilled Labor

Perhaps of even more economic importance than scientists and engineers is the availability of manpower for jobs as technicians and skilled labor. North Carolina's technical and community colleges will continue to play a key role in assuring the availability of this manpower. However, they also face problems similar to the colleges and universities. An increasing percentage of high school graduates who have mastered the basic concepts and skills in science and mathematics must be produced by our public schools if the technical and community colleges are to effectively meet the labor demands of our technological growth.

In addition, many employees in an economy marked by rapid technological change will need to be retrained for new skills and roles perhaps several times in their lifetime. These people will need a firm grasp of basic concepts and skills in science and mathematics and a strong set of learning skills if they are to adapt to these new roles and technologies rapidly and efficiently.

Scientific and Technological Literacy

As we move into a technological age the need for all citizens to be scientifically literate becomes acute. A basic understanding of science and technology and how they effect society is necessary if our citizens are to engage in informed dialog and decision-making on technological issues, if they are to support North Carolina's commitment to research and development, and if they are to intelligently cope with new developments which are affecting the way we work, communicate, travel, learn, and recreate. However, both achievement in science and mathematics and general scientific literacy have deteriorated in the past decade. This deterioration reflects the decline in enrollment, instructional resources, numbers of qualified teachers, and emphasis placed on science and mathematics nationwide. We must adopt a broad understanding of basic literacy which includes an understanding of fundamental scientific concepts, the process of science and the interaction of science and human social values, and we must mobilize our schools to assure this basic scientific literacy for all of our students.

Problems in Science and Mathematics Education -- Overview

Even as the significance of science and mathematics education for our future is being widely recognized, so are the problems and challenges we face in these areas. A number of commissions and task forces have cited evidence of a crisis in science and mathematics education. Such evidence includes declining federal support, declining achievement test scores in science and mathematics, declining enrollment in science and mathematics courses, a critical shortage of physical science and mathematics teachers, lack of funds to sustain meaningful laboratory programs, neglect of science and mathematics in elementary schools, and low participation by women and minorities in science and mathematics courses. Much of these data for North Carolina are summarized in an earlier publication of the N.C. Board of Science and Technology.[1] That report and its recommendations were significant first steps toward addressing the problems. This report is a blueprint for additional steps to ensure excellence in science and mathematics education.

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[1] Recommendations for Improving the Quality of Science and Mathematics Education in North Carolina's Public Schools, Report of the Committee on Science and Mathematics Education of the North Carolina Board of Science and Technology, Raleigh, N.C., July, 1982.

Chapter Two

TEACHER SUPPLY AND QUALITY IN SCIENCE AND MATHEMATICS

Solving the Physical Science and Mathematics Teacher Shortage

Perhaps the most crucial factor affecting the quality of science and mathematics education is the teacher. Yet, the supply of qualified teachers is precisely where North Carolina, and the nation, faces its most critical problem in science and mathematics education.

This is not a criticism of all science and mathematics teachers. It is, rather, an indictment of the societal attitudes and occupational structures which fail to attract, train, and retain qualified teachers in large enough numbers. Evidence of the problem abounds:

- Between 1970 and 1980, the number of teacher education graduates in North Carolina dropped by 62 percent in science and by 72 percent in mathematics.

- Of those who graduate in North Carolina with a degree in science or mathematics education, less than half enter teaching.

- Of those who do enter teaching, 32 percent of those in science and 18 percent of those in mathematics leave during or immediately after their first year in the classroom.

- The supply of available, appropriately certified science and mathematics teachers falls well short of demand in North Carolina, by 40 percent in science and by 76 percent in mathematics.

- Furthermore, the current training and certification system leaves a significant gap, in many cases, between certification and qualification for the teaching assignment.

- The critical teacher shortage has contributed to massive out-of-field teaching in science and mathematics in North Carolina. This problem is particularly acute at the junior high level. During 1980-81:

    - 27 percent (3,669) of all science classes in grades 7-12 were taught by inappropriately certified teachers

    - 41 percent (7,648) of the junior high science courses were taught by inappropriately certified teachers

    - 26 percent (4,010) of all mathematics classes in grades 7-12 were taught by inappropriately certified teachers

    - 49 percent (5,424) of the "Junior High Math" classes were taught by inappropriately certified teachers.

- Evidence suggests that in North Carolina, many teachers are assigned out-of-field unnecessarily. (In fact, large numbers of classes are taught out-of-field in both social studies and English, subjects where there is no critical shortage of teachers.) In 1980-81, approximately 2500 certified science and mathematics teachers were teaching subjects other than science and mathematics or had moved into counseling or administration. In subjects where teachers are in critically short supply, as in science and mathematics, their assignments must be managed much more efficiently to make maximum use of their qualifications.

- Nationwide and in North Carolina, a significant number of the currently qualified science and mathematics teachers will reach retirement in the early 1990s at the same time that the "Echo Baby Boom" causes significant enrollment increases in junior high and high school courses. This could cause even more acute shortages.

In summary, then, the problem of critical shortages of physical science and mathematics teachers, especially at the junior high level, has several key components. Fewer college students are being recruited into teacher education programs in science and mathematics. Of those who graduate, only about one-half actually enter teaching. Many of those who do enter are leaving early in their careers to pursue other occupations at an alarming rate. This has contributed to a large percentage of physical science and mathematics courses being taught by inappropriately certified teachers. Furthermore, a significant portion of the population of appropriately certified science and mathematics teachers is approaching retirement, at which time the shortage will be further aggravated.

Underlying Causes of the Shortage. Many observers have attributed the problem of attracting and retaining capable, qualified physical science and mathematics teachers to the economy. For example, one writer remarks:

> It should come as no surprise that money is at the root of the problem of an inadequate supply of science and math teachers.

They point to industry as the chief culprit, luring both teachers and potential teachers away from the classroom into more lucrative positions requiring similar skills and training.

Clearly salary discrepancies exist, as shown in Table 1. For example, an entry level technical salesperson with a bachelor's degree earns, on average, $621 per month more than a beginning science teacher with very similar technical training. Similarly, an entry level computer programmer would earn $589 per month more than a beginning mathematics teacher, though their training may be quite similar.

It should be noted, furthermore, that entry level salary discrepancies are significantly smaller than those of professionals with five or more years experience. This is because the teachers' salary schedule is "front-loaded."

TABLE 1

COMPARISON OF NORTH CAROLINA SCIENCE AND MATHEMATICS TEACHERS SALARIES TO ALTERNATIVE FIELDS

Entry Level

Field	Monthly Salary July, 1982	10-Month	12-Month	Monthly Salary Discrepancy	10-Month Discrepancy
			(Dollars)		
Teachers[1]					
Classroom Teachers, "A" Cert.	$1,301	$13,010	--	$ 0	$ 0
Alternative Fields[2]					
Assistant Principals, "A" Cert.	1,490	14,900	--	$189	$1,890
Research: Non-Scientific	1,596	15,960	19,152	295	2,950
Mathematics/Statistics	1,741	17,410	20,892	440	4,440
Manufacturing and/or Industrial Operations	1,884	18,840	22,608	583	5,830
EDP - Programming/Systems	1,890	19,900	22,680	589	5,890
Sales - Tech/Scientific Degree	1,911	19,220	23,064	621	6,210
Research - Scientific	1,924	19,240	23,088	623	6,320
Principals (4A-5A State Allotted Teachers)	1,963	19,630	23,566	662	6,620
Rotational Training - Technical	2,001	20,010	24,012	700	7,000
Engineering	2,105	21,050	25,250	804	8,040

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[1] State Salary Schedules for Public School Personnel, 1982-83, (Office of the Controller, State Board of Education, pp. 13-14, 16.

[2] College Placement Council Salary Survey, (Bethlehem, PA: The College Placement Council, 1983, p. 3.

It is not altogether fair, however, to focus only on private sector competition for science and mathematics teachers. As Table 1 also shows, public school administration offers substantially higher salaries than teaching and is a significant competitor for certified science and mathematics teachers.

As a result of this situation, many of the strategies for addressing the shortage, whether implemented or only proposed, have focused on money. They include accelerated salary schedules for science and mathematics teachers only, salary bonuses for remaining in the classroom, college loan forgiveness programs, and differential salaries based on supply and demand.

There is little doubt that some science and mathematics majors are avoiding teaching careers and that many science and mathematics teachers are leaving their classrooms because of higher salaries available in industry and school administration. Certainly teachers' salaries do not compare favorably with many other occupations available to them, especially in technical fields. In fact, between 1970 and 1980, the buying power of the average teacher's paycheck in the U.S. decreased by 17 percent.

Salary alone, however, is not the only factor affecting the recruitment and retention of science and mathematics teachers. In a recent survey of North Carolina science teachers, more than 70 percent said that salary would be "a serious consideration" in determining whether or not they stay in teaching; but over 90 percent said that salary alone would not determine whether they remained in the schools.[1] Other important factors include working conditions (such as the availability of equipment, materials, facilities, and time for effective laboratory-centered instruction), the level of support received from local administrators, and the number and type of non-instructional duties expected of teachers.

An effective solution to the shortage must address both the issues of non-competitive salaries and unsatisfactory working conditions. The question is whether this alone will solve the problem; that is, whether other occupational factors also play an important role in creating the shortage.

Issues surrounding the supply and demand of teachers have been widely studied. Throughout the 1950s and 1960s, when there was a general teacher shortage, initiatives focused primarily on increasing the quantity of available teachers. In more recent years, questions of teacher recruitment and retention have focused more on quality than quantity.

Studies in both North Carolina and the nation have made it clear that:

- there has been a general decline in scores on tests of academic ability among college students choosing education majors and entering teaching;

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[1] Hounshell, Paul B., Science Education Information Network: Report Number Two -- Salary, Unpublished technical report, University of North Carolina, Chapel Hill, N.C., March, 1983.

- education majors score lower than all other majors on tests of academic ability;

- teachers with higher academic ability are likely to leave teaching earlier than those with average or low academic ability.[1]

Thus, the combination of recruitment and attrition patterns is yielding a steadily deteriorating pool of academic talent in the teaching force. This pattern appears to be the result of two major factors: the increase in opportunities for women and minorities in other occupations and the growth in occupations which involve pursuing values similar to teaching but with greater career and financial rewards.

This larger problem contributes to the science and mathematics teacher shortage. That is, increased demand and greater opportunities for academically-able women and minorities have created a shortage of academically-able teachers. Similarly, increased demand and greater opportunities for technically-trained personnel have created a shortage of physical science and mathematics teachers. In both cases, teachers and prospective teachers are choosing more attractive careers in other areas. The science and mathematics teacher shortage, then, is a symptom of the larger problem, but in bolder relief.

Lasting solutions to the physical science and mathematics teacher shortage, then, will address both the peculiar characteristics of supply and demand for technically-trained people and the generic problems of the occupation of teaching.

These generic problems include:

- Limited opportunity for career advancement within the occupation of teaching.

- Undifferentiated roles in the teaching occupation.

- An impoverished and simplistic reward structure which fails to create and renew ambition and achievement.

- Institutional arrangements which inhibit effective performance review, professional growth, and development of a professional ethic and culture.

- A front-loaded salary schedule which is inadequate by any measure.

Ultimately, solving the physical science and mathematics teacher shortage will require solving the problems of the teaching occupation. The significance of the changes required should not be underestimated. In order to compete for qualified teachers, greater investments will be necessary. However, the public should not be asked to pay more for more of the same. Restructuring the occupation to promote and reward excellence is as important as higher pay. These steps will require investments beyond just money -- human and political investments.

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[1] Vance, Victor S. and Schlechty, P.C., "The Distribution of Academic Ability in the Teaching Force: Policy Implications." Phi Delta Kappan, 64:1, pp: 22-27, September, 1982.

The cost of providing outstanding instruction to all of North Carolina's students will be high. The cost of failing to do so will be socially and economically crippling.

Steps Underway. A variety of initiatives are underway across the country to address the salary issues for science and mathematics teachers as well as the larger occupational structure issues:

- Florida's Dade County Public Schools and the United Teachers of DADE (AFT) recently negotiated a three-year contract which includes an incentive pay provision.
- The Richmond City schools in Virginia are giving one-time bonuses of $2,000 to newly hired teachers in high priority areas, such as science and mathematics.
- Houston's Second Mile Plan provides bonuses for critical shortage area teachers as well as for unique campus assignments, outstanding student achievement gains, professional development, etc.
- The State of Tennessee is considering a move toward a plan involving differential roles, responsibilities, and rewards for both classroom teachers and local school administrators.

In North Carolina:

- The Charlotte-Mecklenburg School System has developed a plan to create a career structure to increase opportunities for promotion, economic gain, and public recognition and honor for exemplary teachers. The plan involves definite career stages for classroom teachers with differentiated responsibilities, training, and rewards. Implementation of the plan began with the 1983-84 school year.
- The Legislature's Select Committee on the Department of Public Education recommended in its report to the 1983 General Assembly personnel policies similar to the Charlotte-Mecklenburg Plan. Again the key element was differentiating the responsibilities, recognition, and rewards for classroom teachers.

Recommendations. The recommendations of the Task Force on Science and Technology are intended to accomplish three objectives: 1) We must limit the negative impact of the shortage by immediately getting more qualified physical science and mathematics teachers into the classrooms, by retaining the qualified teachers already in the system, and by better management of the scarce resource of qualified teachers now available; 2) The salary discrepancies and working conditions unique to science and mathematics teachers must be addressed; and 3) The entire occupation of teaching must be upgraded to attract and retain capable teachers in all fields, including science and mathematics.

- The General Assembly, the State Board of Education, and the Personnel Commission for Public School Employees should provide support for local school systems to plan, develop, and conduct innovative staffing plans (the Charlotte Mecklenburg School plan being an example) on a local option basis. The results of these programs over several years may be incorporated into state policies which provide for definite career stages, differentiated responsibilities, differentiated rewards, and significant incentives for outstanding performance among teachers and administrators.

- While moving toward a performanced-based differential salary schedule, the overall level of salaries for school teachers should be significantly upgraded by an across-the-board 20 percent salary increase staged over two years; this should meet the immediate objective of bringing North Carolina's teachers' salaries in line with the national average. However, the longer-term goal must be to make lead teachers' salaries competitive with other occupations to which potentially gifted teachers are now being drawn. The investment of state funds necessary to achieve this goal will range from $100 to $150 million annually.

- The Scholarship Loan Program should be expanded to include at least 100 candidates in physical science and mathematics per year and the amount of the award should be increased from $1500 to $2500 per year. In addition, the wording of the law should be simplified, advertising of the program should be increased, the program should continue to target prospective physical science and mathematics teachers as high priority, and priority should be shifted for recruiting college upperclassmen over rising freshmen. Finally, students who have completed an undergraduate major in science or mathematics and wish to obtain their teaching credentials should be eligible for the program.

- The extended employment provision currently in effect should be expanded to at least 700 teachers and should include qualified middle/junior high school science and mathematics teachers, requiring about $1.2 million in additional funds.

- Local school boards should be encouraged to include teacher supply and demand conditions as a criterion for local salary supplements.

- The State Board of Education should establish criteria and procedures to permit lateral entry into teaching by experts in shortage fields where appropriate, whether on a volunteer, faculty sharing with business, part-time, or full-time paid basis.

- The State Board of Education should encourage local school systems to institute better management policies to eliminate unnecessary out-of-field teaching in their schools. Faculty sharing between schools and school systems where one-half positions need to be filled, notification of adjoining school systems when a shortage area teacher is not re-employed, and the use of team teaching and teaching aides in larger classes are examples of such management strategies.

- Existing reduction-in-force policies should be revised to include local supply and demand as a criterion for reductions-in-force, in addition to seniority and tenure. This will require the General Assembly to amend the Fair Employment and Dismissal Act.

- The State Department of Public Instruction should assist local school systems to pursue an aggressive program of recruiting physical science and mathematics teachers from approved programs both in North Carolina and in other states. Funds should be provided to permit hiring first-year teachers no later than June 1. In addition, job descriptions for teaching positions should more accurately and completely reflect the responsibilities of teaching.

- The State Board of Education should require local school systems, beginning in 1985-86, to give priority to new applicants with proper certification over current teachers who are teaching physical science or mathematics out-of-field and who are not actively seeking certification for the subjects they are teaching. Exceptions must be approved by the local school board.

- The State Board of Education should permit and encourage local school systems to provide extra pay to qualified physical science and mathematics teachers who agree to teach an additional course beyond the normal full load, where this is needed.

- The State Board of Education should establish a fellowship program to provide for full-time and/or summer study for adults with appropriate science or mathematics expertise, but who do not have teacher certification, to retrain and earn physical science or mathematics certification.

- The General Assembly should adopt legislation to provide a financial incentive for colleges and universities to produce more qualified teachers in high demand-critical shortage areas rather than areas of low demand and oversupply.

- The State Board of Education should support and encourage local school systems to provide the best possible working environment for all teachers. Organizational and managerial steps should be taken to relieve teachers of non-instructional duties, such as lunchroom and bus monitoring and excessive paperwork. (Specific recommendations regarding equipment, facilities, time, etc. are included in other sections of this report).

Teacher Training and Certification

While it is essential to increase the supply of physical science and mathematics teachers available in North Carolina, we must also give careful attention to the quality of those teachers. This requires that significant steps be taken to improve both their training and certification.

Certification. The purpose of teacher certification is to provide the state with a mechanism to assure a minimum level of training for its public school teachers. Certification does not guarantee that a teacher will be competent. However, when the system is sound, it can provide a reasonable proxy for teacher qualifications.

Much attention has been given in recent months to issues surrounding teacher certification in North Carolina. The primary focus of this attention has been the level of out-of-field teaching in the state. Reports by the Department of Public Instruction, the North Carolina Board of Science and Technology and the N.C. Center for Public Policy Research have documented alarmingly high levels of out-of-field teaching in physical science, mathematics, reading, and other subjects. However, out-of-field teaching is only one of several important issues surrounding certification of teachers in science, mathematics, and other areas.

Current Policy. Under current policy in North Carolina, a person may be initially certified by the State Board of Education upon completion of an approved program of study at one of more than forty colleges and universities, with the recommendation of that institution and successful completion of the National Teachers Examination. Following the initial certification, that person must renew his/her certificate by earning nine (9) units of renewal credit every five years. Up to three of these units may be earned through three or more years of teaching experience.

Certificates had been issued for grades K-3, 4-9, and 7-12, although policy changes were recently adopted to issue certificates for K-4, 4-6, subjects in 6-9 and subjects in 9-12. Under the previous policy, for grades 4-9 a general certificate had been issued, but teachers may, and sometimes must, have earned a concentration in one or more subjects by taking anywhere from 15 to 30 semester hours coursework in that subject.

Secondary Science and Mathematics Certification. Secondary certificates for grades 7-12 have only been issued in particular subject areas. This is also true of the new middle grades (6-9) and secondary (9-12) certifications. Only one secondary mathematics certificate had been issued. A teacher holding this certificate is considered qualified to teach any mathematics course in grades 7-12. Teacher training institutions generally require about 36 semester hours of mathematics courses, in addition to 12 hours of educational psychology/sociology and a one semester methods course with a practicum.

In secondary science, six different certificates may be earned: General Science (37 percent)*, Earth Science (0.8 percent)*, Biology (35.4 percent)*, Chemistry (8.1 percent)*, Physical Science (5 percent)*, and Physics (1.9 percent)*. Teacher training institutions require about 25 percent of the students' coursework (30 semester hours) in their subject major. About 70 percent of these teachers holding the General Science certificate have a concentration in biology, as opposed to the physical sciences.

Problems. A variety of problems must be addressed to strengthen certification in science, mathematics and other subjects:

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* Percent of N.C. secondary science teachers holding this certificate.

- There is a recognized gap between certification and qualification which needs to be eliminated. Teacher education programs vary widely across the state with regard to course requirements in science and mathematics for each certificate. The inequities should be addressed to assure that the requirements are uniformly adequate. In addition, there are some qualified individuals who are unable to teach because they are not certified. Some mechanism is needed to provide access to the classroom for such individuals while assuring that their students are being adequately and professionally served.

- The mechanism for assuring the quality of teacher education graduates is state program approval. However, the quality of programs which are currently approved varies significantly.

- Past policy has permitted any teacher with an intermediate certificate, regardless of subject matter concentration, to teach any course in grades 4-9. Thus, a teacher with only one college mathematics course was "legitimately certified" to teach ninth grade algebra. Similarly, some teachers with no college level physical or natural science courses were "legitimately certified" to teach life science, earth science, and physical science. This led to significant numbers of courses being taught by unqualified teachers in the middle grades.

- In science, the general (300) science certificate permits one to be legitimately assigned to teach any secondary science course. Most of the teachers with this certificate have concentrated their coursework in biology. Yet, many are teaching chemistry, physics, earth science, and physical science and can still be counted in-field.

- Certificates can currently be renewed with the equivalent of as little as four semester hours of college coursework (two courses) every five years. Furthermore, none of the renewal credit need be earned through formal college courses or in the teacher's field of certification or assignment. Meeting current requirements does not assure that a teacher is remaining relatively current in either subject matter or methods, or that it improves his/her classroom performance.

It is clear that if teacher certification in North Carolina is to be an effective mechanism for assuring the citizens of the state that their children's science, mathematics and other teachers have received adequate formal training, significant policy changes are needed.

New Policies and Programs. At the May, 1983 State Board of Education meeting, a new In-field Assignment Policy was adopted. Until this time, there were no laws or rules regulating out-of-field teaching in North Carolina. This new policy requires, as of the 1983-84 school year, that all teachers hold a certificate or provisional certificate in their area of major assignment (one-half day or more). A provisional certificate requires that the teacher be working toward full certification in that field at the rate of at least six (6) semester hours of earned credit per year. In addition, if a teacher is assigned to teach a course for less than half a day, she/he must hold at least an endorsement or provisional endorsement that field. This endorsement would be based on 18 semester hours of coursework in that subject. A provisional endorsement would be granted only to a teacher who is working toward endorsement in the field.

The Governor's Task Force on Science and Technology supports the intent of the new in-field assignment policy. The state must move rapidly to ensure that every child receives instruction from qualified teachers. It is the right of every child and parent to expect qualified teachers in every classroom. It is the responsibility of state and local leaders to provide and implement policies which are responsive to this need.

The need is clear. Out-of-field teaching in science, mathematics, reading, and other subjects has reached unacceptable levels. This is due in part to supply and demand pressures. Those pressures must be countered by providing a career structure and a reward system to attract and retain sufficient numbers of qualified teachers in all fields.

However, much of our current problem is the result of policies and management decisions which assign teachers out-of-field unnecessarily and fail to set up the expectation that classes be taught in-field except where extreme circumstances preclude it.

The new policy addresses much of this need. It promotes a total in-field philosophy; it provides flexibility for short-term local shortages of teachers; and it limits repeated out-of-field assignments with the same teacher or class. It is critically important that this policy be enforced with integrity to assure that teachers receive the additional training necessary.

In addition, the Quality Assurance Program, which has been under development for five years, was recently approved by the State Board of Education. The framework for this program, developed by the State Board of Education and the UNC Board of Governors, includes:

- The development of screening procedures to ensure that college students meet acceptable standards in the general education fields of English, literature, fine arts, social studies, mathematics, and science, before admittance to teacher preparation programs.

- Clarification of the competencies to be included in teacher preparation programs "in order to produce competent and effective teachers."

- The development of a more effective, more systematic student teaching program.

- The development of a test "which would serve as part of the final pre-service evaluation and would be a prerequisite for initial certification."

- The development of an evaluation system for use with all individuals under initial certification prior to the granting of career status to them.

The Governor's Task Force on Science and Technology strongly endorses the implementation, review and continuing improvement of the Quality Assurance Program. The movement toward rigorous screening procedures and toward a more structured student teaching experience should strengthen the pool of incoming teachers significantly.

In the absence of other initiatives, however, this policy of raising standards may also lead to declining numbers of teacher education graduates in North Carolina. Therefore, we strongly recommend that initiatives for attracting and retaining greater numbers of academically able, competent teachers be implemented in conjunction with the Quality Assurance Program.

The University of North Carolina, in conjunction with the Department of Public Instruction and the N.C. School of Science and Mathematics, recently began developing a statewide network of Centers of Science and Mathematics. These centers are an important step toward a more effective program of preservice and inservice training for science and mathematics teachers. In the course of the development of these centers, a comprehensive review of the appropriateness and quality of content and methods courses for science and mathematics teachers should be undertaken. In addition, steps should be taken to assure that teachers are adequately prepared to integrate instruction in science and mathematics with the humanities and social sciences. Similarly, teachers in these other disciplines should be adequately prepared to provide learning experiences which deal with pressing social and personal issues resulting from scientific and technological development. Such issues include environmental concerns, the social impact of new technologies, the effects of technology on personal lifestyles, crucial ethical issues in science, and the social impact of economic changes.

Recommendations. Given the above review, the Task Force on Science and Technology recommends the following:

- The State Board of Education should include the following requirements in its guidelines for middle grades (6-9) teacher education program approval and reapproval:
  - All program reapprovals must be supported by an adequate catalog description of requirements for each certificate.
  - Every middle grades (6-9) program should require in the general core at least three content courses in college mathematics resulting in competence in algebra, geometry and trigonometry, and at least one content area course in each of life, earth, and physical science.
  - Middle grades (6-9) mathematics concentrations must include at least 18 semester hours of college level mathematics/statistics/probability/computer sciences courses, at least one course in the methods of teaching mathematics (not a shared course), and part of the student teaching assignment in mathematics.
  - Middle grades (6-9) science concentrations must include at least two college level courses each in life, earth and physical science (21 semester hours), at least one course in the methods of teaching

sciences (not a shared course), and part of the student teaching assignment in science.

- The State Board of Education should restructure the secondary science certification system to:
  - reduce the number of certificates from six to three: Middle Grades (6-9) Science, High School Life science, and High School Physical Science;
  - establish more uniform expectations for the number and type of subject matter courses to be taken;
  - permit and encourage dual certification by awarding a second science certificate for an additional 18 semester hours in the second science subject area.
- The State Board of Education, the General Assembly, the University of North Carolina General Administration and the Association of Independent Colleges and Universities should establish a study commission to examine the feasibility of moving toward a required five-year college program for initial certification of teachers in North Carolina.
- The State Board of Education should establish procedures and guidelines for allowing and encouraging lateral entry into teaching by experts in subjects where teachers are in critically short supply, such as visiting chemists, physicists, and mathematicians who would teach on either a part-time or full-time basis.
- The State Board of Education should amend its current certificate renewal policy to increase the number of Continuing Education Units (CEU) required from 9 to 15 units of credit every five years; require that at least nine of the CEUs be earned in the subject area (content and methods) of the teacher's certification, assignment, or endorsement; and require that at least six of the CEUs be earned in coursework through an accredited college or university.
- Efforts should be made to secure funds from both state and private sources for the purpose of supporting elementary and secondary school teachers who wish to attend professional meetings, conferences and workshops on science and mathematics content and instructional methods.
- Inservice workshops and summer institutes should provide adequate emphasis on integrating curricula in science and mathematics with instruction in the humanities and social sciences, with an emphasis on science and society issues.

Chapter Three

PUPIL ENROLLMENT AND PERFORMANCE IN SCIENCE AND MATHEMATICS

The final measure of the effectiveness of any educational program is the level of participation and achievement of students. Nationwide in science and mathematics education, the challenges are clear. Both enrollment in high school science and mathematics courses and achievement in science and mathematics at all levels leave much to be desired.

Part I

Secondary School Enrollment and Performance

Pupil Enrollment

Declining pupil enrollment in science and mathematics is an issue of national concern. According to the Education Commission of the States report on Education for a High Technology Economy:

- Between 1960 and 1977, the proportion of high school students enrolled in science in the U.S. declined from 60 percent to 48 percent.
- Despite recent increases in mathematics and computer science enrollments, one-half of all high school graduates in the U.S. take no mathematics or science beyond the tenth grade.

This decline in enrollment is occurring in the midst of increased demand for scientists, engineers and technicians. Furthermore, as high school enrollment declines through the rest of this decade, not only the numbers, but the proportion of students preparing for post-secondary training in technical fields will need to be increased.

This national pattern of declining enrollment in science and mathematics is reflected in North Carolina:

- Enrollment in secondary science and mathematics courses in North Carolina has declined steadily over the past decade at a greater rate than the general enrollment decline.
- While the decline in science and mathematics enrollment seems to have stabilized somewhat, enrollment after tenth grade, when minimum graduation requirements have been satisfied, drops dramatically, by about 65 percent in science and 55 percent in mathematics. This indicates that, given a choice, most high school students are not choosing science and mathematics courses as electives.

Patterns of enrollment in the various science and mathematics courses are also of some concern. As can be seen from Figures 1 and 2, it is difficult to determine from available enrollment data just what kind of curriculum North Carolina's students are experiencing in science and mathematics. What is clear is that a large number of students are choosing not to take Physical Science and Algebra I. These key "gatekeeping" courses determine whether students can proceed to the higher level physical science and mathematics courses which will prepare them for technical training or science and engineering programs at the college level. This enrollment decision, then, which is usually made at the ninth grade level, is essentially a career decision. Choosing not to take Algebra I or Physical Science can effectively exclude a student from the growing career opportunities in our technological economy.

Achievement in Science and Mathematics

Again, the national pattern of decline in achievement in science and mathematics is unmistakable and is reflected in data from North Carolina:

- National data on student achievement in science and mathematics indicate that, while the performance of students who intend to pursue careers in technical fields is no worse than in the recent past, the achievement of the majority of students has declined in both science and math for over a decade. In fact, national mean mathematics scores on the SAT have declined steadily since 1963.

- While the most recent assessments indicate that mathematics achievement is improving with regard to simple arithmetic skills, students continue to fall short in the more complex skills of problem-solving and critical thinking. It is, moreover, these problem-solving and thinking skills which are likely to be in greatest demand in the adaptable workforce needed by technologically-advanced businesses and industries.

- In North Carolina, mean SAT mathematics scores run at about 9 percent below the national average and have paralleled the national declines.

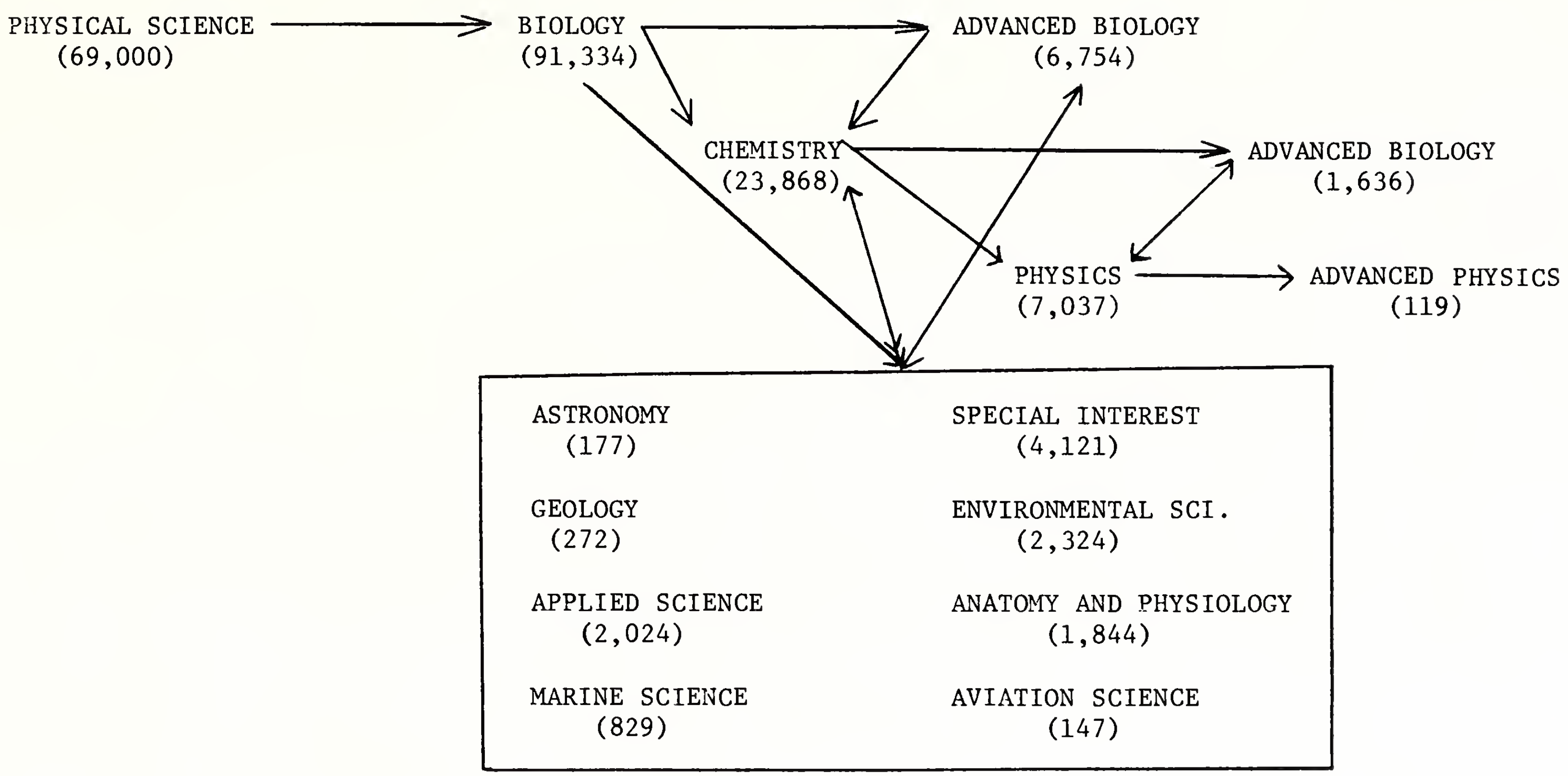
- Since the implementation of the Competency Testing Program in North Carolina, student scores have risen steadily. Yet, several thousand students fail to pass this test annually.

Minority Enrollment and Performance in Science and Mathematics

Minorities are significantly underrepresented in the fields of science, mathematics and engineering. This situation should cause concern for two reasons. First, if blacks and other minorities are to enjoy equal economic opportunity, it is essential that they actively participate in significant numbers in these fields which are on the cutting edge of economic growth. Second, the demand for technically-trained personnel at all levels, from highly skilled technicians to research scientists, is expected to continue to

FIGURE 1

HIGH SCHOOL SCIENCE ENROLLMENTS IN NORTH CAROLINA

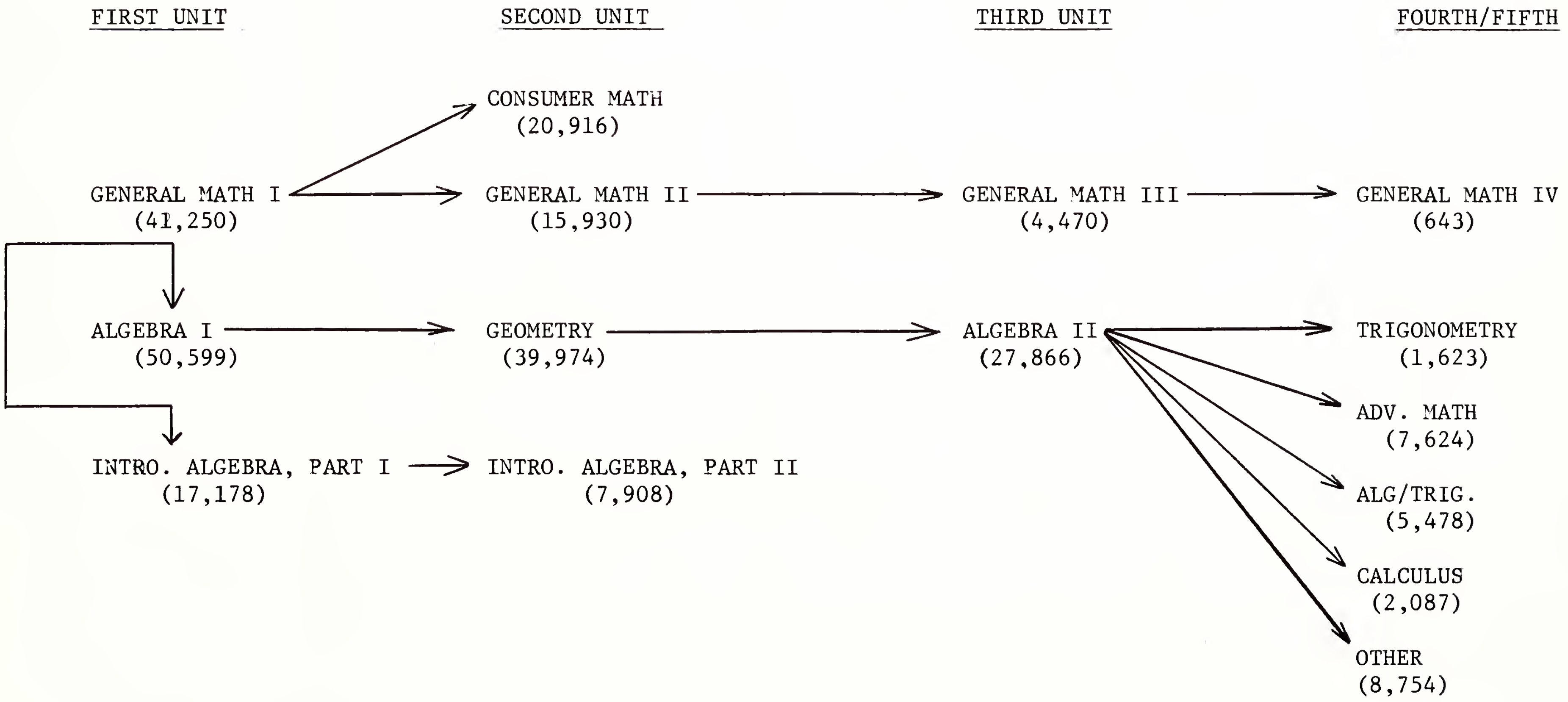


(Arrows indicate course sequences which are allowed)

Source: N. C. Public Schools
Statistical Profile, 1982

FIGURE 2

HIGH SCHOOL MATHEMATICS ENROLLMENT IN NORTH CAROLINA



(Arrows indicate which course sequences are allowed)

Source: N. C. Public Schools Statistical Profile, 1982 outpace the supply. Minorities, as well as women, represent an enormous pool of largely untapped talent which must be developed and employed if our economy is to have the human resources to remain competitive.

The low level of minority participation in technical fields is most readily seen in the college enrollments in these areas. Table 2 below indicates that minorities accounted for only 5 to 8 percent of the total graduate enrollment nationally in all of the sciences in 1978.

TABLE 2

GRADUATE ENROLLMENTS OF WOMEN AND MINORITIES, BY FIELD FALL, 1978, UNITED STATES

Field	Total Enrollment	Women Number	Women Percent	Minorities Number	Minorities Percent
Agriculture and Natural Resources	16,923	3,613	21	844	5
Biological Sciences	41,785	14,776	35	3,015	7
Engineering	57,123	3,984	7	4,523	8
Physical Sciences	35,279	6,247	18	1,944	6
All Fields	1,076,795	498,995	46	111,625	10

Source: Pepin, Andrew J., Fall Enrollment in Higher Education 1978 (to be published).

Even more significant are the enrollment figures for full-time graduate programs in doctoral institutions (Table 3). These are the students who will become tomorrow's research scientists. Blacks represent only 2.7 percent of all full-time doctoral students in the sciences in 1979. That is less than one-fifth of the foreign student enrollment.

TABLE 3

FULL-TIME GRADUATE ENROLLMENT IN DOCTORATE INSTITUTIONS BY RACE/ETHNICITY, 1979, UNITED STATES*

	Total	Black[+]	Am. Indian Alaskan	Asian/Pac. Islands	Hispanic	White[+]	Foreign
Total, All Fields..	100.0	2.7	.2	1.8	1.9	74.0	19.5
Engineering	100.0	1.1		2.2	.9	52.7	43.0
Physical Sciences..	100.0	1.3	.1	2.0	1.6	70.8	24.2
Environ. Sciences..	100.0	.7	.1	1.1	1.3	83.5	13.4
Math/Comp Sciences.	100.0	1.5	.1	1.9	1.4	65.0	30.2
Life Sciences......	100.0	2.1	.2	2.0	1.8	81.8	12.2
Agricultural.....	100.0	.9	.1	.7	1.2	75.4	21.6
Biological.......	100.0	1.3	.1	1.3	1.6	83.3	11.4
Health...........	100.0	3.9	.4	2.1	2.3	82.6	8.7
Psychology.........	100.0	4.1	.2	1.6	2.8	88.2	3.0
Social Sciences....	100.0	5.4	.4	1.3	2.7	73.3	16.9

* In 3,958 responding departments

+ Non-Hispanic

Source: National Science Foundation, unpublished data.

TABLE 4

UNDERGRADUATE* ENROLLMENTS OF WOMEN AND MINORITIES BY FIELD, FALL 1980

Field	Total Enrollment	Women		Minorities	
		Number	Percent	Number	Percent
Agriculture and Natural Resources	125,102	40,941	33	9,541	8
Biological Sciences	233,298	114,839	49	43,787	19
Engineering	540,875	69,490	13	72,639	13
Physical Sciences	133,738	39,444	29	14,844	11

* Full-time and part-time

** Includes Black, Non-Hispanic, American Indian/Alaskan native, Asian or Pacific Islander and Hispanic.

Source: NCES (unpublished data).

Of course, graduate enrollments are severely constrained by the numbers of undergraduates who have prepared for further training through an undergraduate major in a science, mathematics or engineering field. Here again, the figures are cause for concern. Minority undergraduate science enrollments in Fall, 1980 ranged from 8 percent in agriculture and natural resources to 19 percent in biological sciences (Table 4).

Low enrollments of minorities in undergraduate science majors place limitations not only on the available scientific and engineering manpower, but also on the pool of qualified individuals for technical sales, management in technical and manufacturing firms, technical education, and candidacy for medical and allied health professional schools.

Again, however, the problem of undergraduate enrollment lies primarily at another level. Although many colleges and universities are making a concerted effort to recruit minorities to these technical fields, they are having only limited success because of the restricted pool of students from which they may recruit. The limitation comes from low minority enrollment in high school courses which are legitimate prerequisites to a college major in science, mathematics and engineering. Nationally, while 81 percent of the white high school seniors in 1980 had taken Algebra I, only 68 percent of the blacks had. Similarly, some 60 percent of the white seniors had taken geometry and 50 percent had taken Algebra II, while only 38 percent of the black seniors had taken geometry and 39 percent had taken Algebra II (Table 5). Comparable data for North Carolina are not available.

TABLE 5

PERCENT OF 1980 HIGH SCHOOL SENIORS IN U.S. TAKING MATHEMATICS COURSES, BY COURSE TITLE AND RACIAL/ETHNIC GROUP

	Algebra I	Geometry	Algebra II
Black	68	38	39
White	81	60	50
Hispanic	67	39	38
Amer. Indian/Alaskan Native	61	34	32
Asian or Pacific Islander	88	79	76

Source: "High School and Beyond -- A National Longitudinal Study for the 1980's", p. 5.

The problem of insufficient minority presence in science and engineering occupations and in science, mathematics and engineering degree programs, as well as technician training programs, may best be dealt with by increasing minority enrollment in courses at the junior and senior high level.

Decisions about which courses minority students take in science and mathematics are often made quite early (6th-9th grades) and are frequently made for the student by a homeroom teacher or counselor, with little input from the home. Even if the decisions were made by the student and his/her parents, many are unaware of the variety of technical careers open to them and the academic paths which lead to these careers, and that certain decisions foreclose these future options.

The underlying problem seems to have several dimensions:

- Low Expectations. Many teachers, counselors and black students themselves have very low academic expectations for blacks. This is a problem of attitudes, which must be dealt with in both the white and black communities, in school and out of school.
- Lack of an Effective Counseling Mechanism. For a variety of reasons, traditional counseling mechanisms seem unable to respond effectively to this problem. A new mechanism of counseling is needed for both academic decisions and for career awareness among blacks with regard to science, mathematics and engineering.
- Lack of Awareness and Interest. The problem of low minority presence in technical fields compounds itself, since there is a shortage of appropriate role models in these fields for black children and a lack of exposure to these fields through family, friends and neighbors.

Women in Science, Mathematics and Engineering

The problem of low minority participation in science, mathematics and engineering is paralleled by a similar lack of participation by women. Tables 2 and 4 indicate the need for increased enrollments of women at the graduate and undergraduate levels, particularly in physical sciences and engineering. While female enrollment in these degree programs has shown marked improvement in the past decade, less than one-fourth of all physical science and engineering degrees awarded in North Carolina in 1982 were to women. Like minorities, a disproportionate share of women are excluded from the economic opportunities offered by scientific and technological advance.

While public school enrollment data in science and mathematics are not collected by sex in North Carolina, national data indicate that the problem begins at the early levels. According to the National Science Foundation, female enrollment falls short of male enrollment nationwide in geometry, advanced algebra, trigonometry, and calculus at the high school level.[1] In addition, according to recent national assessments on science and mathematics, the gap between male and female attitudes and achievement in science and mathematics grows significantly between ages 9 and 17.

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[1] National Science Foundation, Office of Scientific and Engineering Personnel and Education, Science and Engineering Education: Data and Information, (Wash. D.C., 1982), pp. 57-59.

The causes of this problem have been attributed to general public attitudes towards females, sex stereotyping in the classroom and curriculum, lack of female role models in scientific and engineering fields, and sex stereotyping among peers. Successful programs for developing more positive attitudes and better performance in science and mathematics among females have been developed. Some have been successfully implanted in programs offered by the N.C. School of Science and Mathematics and other schools. Significant statewide efforts are needed, through teacher awareness training, special supplementary programs for female students in science and mathematics, providing female role models from scientific and engineering fields, and awareness programs for parents of female students.

Responses

Several responses to the problems discussed above are already underway. In many local communities, efforts to increase student interest and participation in science and mathematics have been initiated. Programs sponsored by the North Carolina Science Teachers Association, the North Carolina Council of Teachers of Mathematics, the North Carolina Student Academy of Science, and the State Department of Public Instruction include competitions and conferences for fostering student interest. Statewide activities also include:

- Math Counts, a statewide competition involving local, district and state mathematics competitions for students in grades 7 and 8. This new program is sponsored by the Professional Engineers of North Carolina and is an outstanding example of a working partnership for school improvement.

- The North Carolina Scholars Program, recently implemented by the State Board of Education, provides incentives and recognition for students who take a more rigorous course of study than the minimum graduation requirements, including 3 units of science and 4 units of mathematics.

- Increased Graduation Requirements. The State Board of Education recently raised the state minimum graduation requirement from 18 to 20 units. These two additional units are undesignated, but it is hoped that many students will take mathematics and science courses in addition to the two units of each which are currently required.

- The North Carolina Consortium for Minorities in Science, Mathematics and Engineering, recently established to link local programs across the state which provide incentives and support to minority students with an interest in science and mathematics.

In addition, the Mathematics Curriculum Study Committee of the State Department of Public Instruction has recommended several steps to encourage communication among secondary schools and institutions of higher education. One recommendation calls for the creation of a committee representing the mathematics departments of public and private schools, colleges and universities (public and private), technical and community colleges, and the Mathematics Division of the SDPI. The Curriculum Study Committee Report contends:

Techniques, theories, points of emphasis and priorities need to be updated as college, university and technical school programs change. It is essential that those in the public schools who are responsible for instruction in mathematics be kept informed about these changes. It is likewise essential that college and university educators, especially those responsible for teacher training, be informed about what is happening in the public schools.

The Mathematics Curriculum Study Committee has also recommended the following:

A. Four-year college degree credit [should] not be awarded for courses in which the level of content is equivalent to that of Algebra I or Geometry.

B. Colleges and universities [should] devise and maintain more stringent entrance requirements in mathematics, utilizing high school grades and SAT scores.

C. If an institution of higher learning does admit students who are deficient in mathematics, then that institution should expect to offer remedial, non-credit mathematics courses.

As long as colleges, universities and technical schools award credit for introductory level courses which have been traditionally taught at the high school level (i.e., Algebra I and Geometry), many college-bound students will not take these courses in high school. Thus, offering remedial work for college credit encourages students not to do this work in high school where it should, in fact, be done and expands thereby the demand for remedial work at the college level. Fewer students will opt out of mathematics early in high school if our institutions of higher learning adopt the suggestions in this recommendation. It has been documented that students who discontinue the study of mathemtics early in high school severely limit their subsequent educational and vocational options. Many doors, both in college-level programs and in vocational training, are closed to those students.

The Task Force endorses these recommendations, urges similar processes for science, and encourages the state's colleges and universities to work closely with the State Board of Education to follow through with implementation.

Recommendations

Improving enrollment and performance of all students in science and mathematics will require overall improvement of these instructional programs, as the strategy presented throughout this report is intended to accomplish.

The following recommendations of the Task Force are intended to directly affect these problems.

- By the 1986-87 academic year, the State Board of Education should require all students to master basic algebraic concepts for graduation from high school. For most students, this will imply successful completion of Algebra I. For a few, it may mean specialized coursework in algebra.

- Provision for annual parent-educator-pupil conferences for each child in North Carolina's public schools to make explicit, shared decisions with regard to future enrollment and career goals at the secondary level and clear decisions on instructional goals at the elementary level.

- Every junior high and middle school should conduct an annual program for students and parents to explain long-term consequences of enrollment decisions, to introduce early career guidance, and to highlight the importance of continuing enrollment in critical academic subject areas such as science and mathematics. Particular emphasis should be given to females and minorites in these programs.

- The State Board of Education should require each junior high and middle school to institute a career exploration unit which includes an emphasis on technical careers.

- The State Board of Education should recommend that local school systems develop a program using the resources of professional societies, retired scientists and engineers, technical employees from business and industry, and scientists and engineers from colleges and universities to highlight opportunities in science and technology, especially for minority and female students.

- Pre-service and in-service training of counselors should be strengthened to include more and better preparation for career counseling, especially in emerging technical careers. Care should be taken to select appropriate role models for female and minority students.

- A career awareness series should be developed by the N.C. Center for Public Television, the Department of Public Instruction, and the N.C. Department of Public Telecommunications, to be focused on scientific and technical careers, for broadcasting on public television and in public schools.

- The state should provide formal support of about $50,000 annually to the N.C. Council for Minorities in Science, Mathematics and Engineering through the Board of Science and Technology, the Department of Public Instruction, the Department of Community Colleges and the UNC system.

- In-service education for principals, through the Annual Leadership Conference and the N.C. Principals Institute, should encourage greater emphasis on science and mathematics, and on the preparation of students for technical training and careers.

Part II

Elementary Science and Mathematics Education in North Carolina: The Heart of the Enrollment and Performance Problem

An underlying cause of the problems of pupil enrollment and performance in science and mathematics at the secondary level is the quality of students' experiences with these subjects at the elementary level. Unfortunately, most of the responses to this problem, particularly in the public policy arena, have focused almost exclusively on secondary high schools. Yet, it is necessary to give significant attention to elementary instruction if sustained, long-term improvement in these disciplines is to be achieved.

Rationale

Effective education at the elementary level provides the foundation upon which future learning builds by creating productive attitudes toward learning and by providing mastery of fundamental skills and concepts which are prerequisites for future academic success. A child's failure to internalize fundamental ideas at an early age threatens all future learning. Because a child's self-concept becomes entwined with performance and willingness to attempt to master new tasks, quality education at the elementary level is critical.

North Carolina's Primary Reading Program has demonstrated the wisdom of effective programming and investment in early levels of schooling. Effective K-12 science and mathematics education will require similar attention to the elementary program to ensure that students are both willing and prepared to take advantage of improved science and mathematics programs at the high school level.

The need for stronger elementary science and mathematics programs is clearly demonstrated by the decline in student interest in these subjects during the early school years. According to a 1979 National Assessment of Educational Progress report, by the end of the third grade, nearly half of the students feel they would not like to take science and only 21 percent of the eighth graders have a positive attitude toward science courses. Similarly, the popularity of mathematics drops from a high of 48 percent in grade 3 to a low of 18 percent in grade 12. Clearly, there is a need for stronger elementary science and mathematics programs to build the attitudes, interest and competence which will lead to improved enrollment and performance in secondary schools. Essential components of strong elementary science and mathematics programs include:

- Committed School Leadership. Principals must be prepared for and committed to their role as instructional leader in science and mathematics as well as other subjects. No elementary school program can long succeed without the enlightened leadership of the principal.

- Well Qualified Teachers. Teachers must be capable and comfortable with their subject matter and methods, including effective hands-on learning in science and mathematics.

- Appropriate Curriculum. Science and mathematics curricula must be interesting to the student, appropriate to the child's level of development, well articulated from grade to grade, and comprehensive enough to adequately prepare students for future academic work.

- Adequate Instructional Materials. Research has made it clear that effective elementary instruction in science and mathematics requires an active, "hands-on" approach. To make this possible, teachers must have the equipment, materials, models, and facilities readily available -- and know how to use them. A strong elementary science and mathematics program, then, will provide the materials necessary to move beyond a sterile textbook, paper and pencil approach to active student involvement in problem solving and concrete learning.

- Adequate Time. Research has clearly shown that the time students spend actively engaged in academic learning is crucial to their achievement. Adequate time for effective instruction in science and mathematics, as well as language arts and other subjects, must be provided in elementary schools.

- Academic Feedback and Program Accountability. Students perform better when they receive academic feedback on their performance. Furthermore, teachers can tailor instruction to particular students' needs, given appropriate assessment of the students. In addition, research has shown that significant school improvement, especially in elementary schools, takes place when a school is willing to subject itself to objective measures of its success. North Carolina's Annual Testing Program is a case in point for each of these statements. For these reasons, we believe that a strong, valid program of testing in science and mathematics is essential to improving elementary instruction in these subjects.

Problems and Recommendations

Having identified these key components of strong elementary programs in science and mathematics, we must recognize the problems we face in each of these areas and take bold steps to correct them.

Leadership. Numerous studies have shown that the principal plays a key role in strengthening elementary school programs. Where a knowledgeable, competent principal assumes the role of instructional leader, a school is likely to be strong and effective. However, many principals do not feel qualified to supervise instruction in science and mathematics. According to a recent survey of elementary principals, some 53.4 percent did not feel that they were "well-qualified" to supervise instruction in science; 37.2 percent did not feel that they were "well-qualified" to supervise instruction in mathematics. It is important that elementary school principals be prepared for this role through outstanding inservice activities designed to inform them of the importance of effective science and mathematics instruction and to acquaint them with models of effective elementary programs in these subjects. The N.C. Board of Science and Technology has already sponsored a series of workshops for elementary principals on effective science instruction as a follow-up to the Principal's Leadership Conference. The Task Force therefore recommends:

o That the State Board of Education extend the work begun in these workshops by providing staff development funds for further inservice training for principals in effective elementary science and mathematics education.

Teachers. The typical elementary school teacher in North Carolina is a woman with approximately ten years of teaching experience. Her strengths are in language arts and social studies. Her methods for teaching reading are relatively sophisticated and effective. However, she has had only one or two courses each in science and mathematics in college and one course or less in science and mathematics teaching methods, since this is all that was required for certification (see Table 6). Furthermore, it is likely that she prefers teaching language arts and feels relatively uncomfortable with science and mathematics. In a 1977 national survey, only 22 percent of the elementary teachers perceived themselves as "very well qualified" to teach science, and less than half thought they were "very well qualified" to teach mathematics. In contrast, 63 percent thought they were "very well qualified" to teach reading (see Figure 3).

It is clear, then, that steps should be taken to ensure that teachers receive adequate training in science and mathematics and in science and mathematics teaching methods to feel confident and to perform competently in these subjects. Thus, it is recommended:

o That all colleges and universities in North Carolina which award Primary (K-4) and/or Intermediate (4-6) Certification require prospective teachers to satisfactorily complete at least three courses of three semester hours each in mathematics, three courses in science, and one course each in science methods and mathematics methods. Furthermore, we recommend that a science and mathematics content area exam be required for certification at these levels.

We recognize that these requirements will place additional demands on an already crowded course of study in schools of education. Yet, in the best interests of elementary school students, these requirements should be implemented even if this will require an additional semester or summer term for graduation and certification as an elementary school teacher.

Beyond these course requirements, however, it is important to ensure that the coursework taken be appropriate to the needs of elementary teachers. There should be a match between the needs of elementary teachers and the content covered and methods employed in the required coursework for certification. To achieve this, the Task Force recommends:

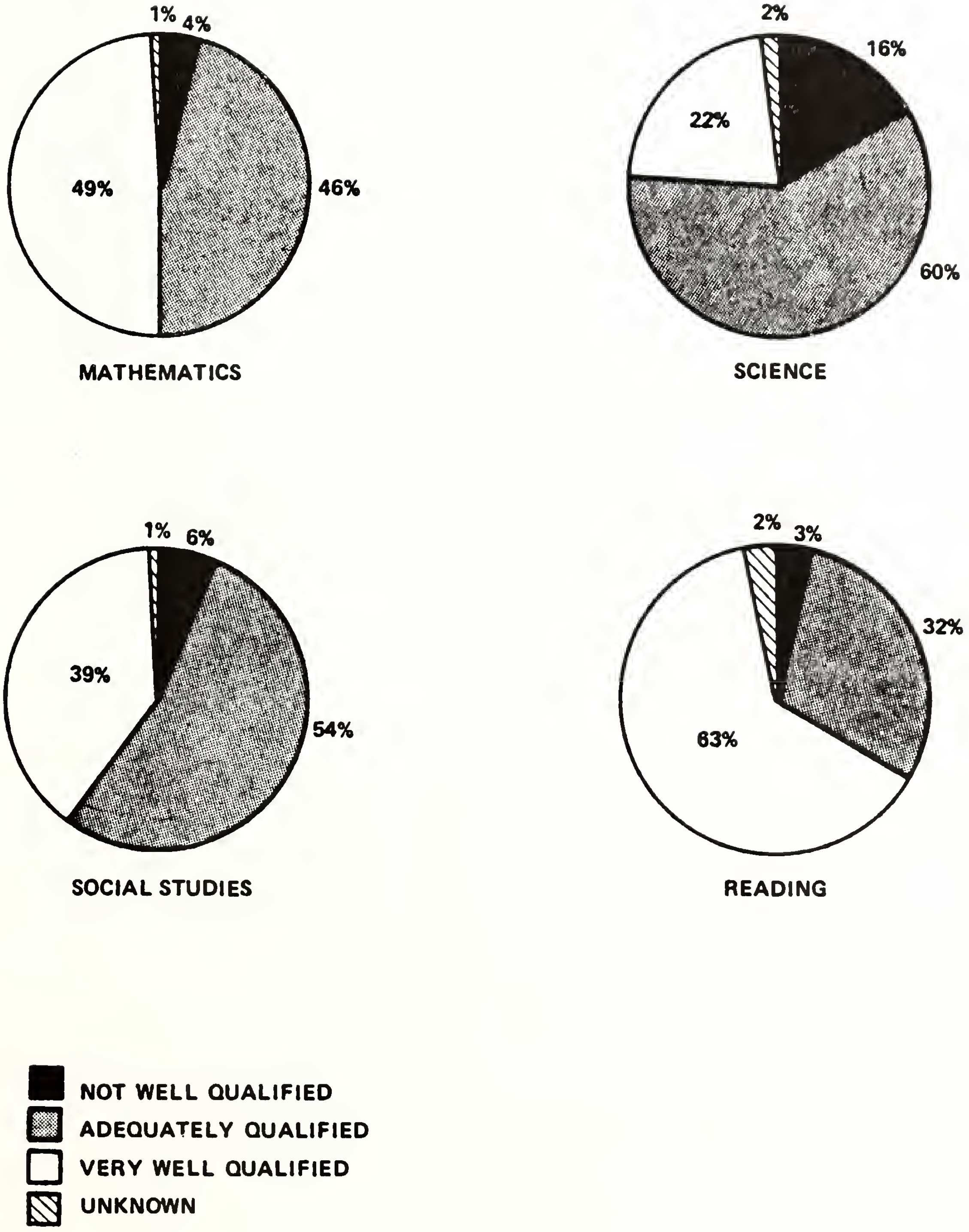
TABLE 6

PRIMARY CERTIFICATE REQUIREMENTS IN SCIENCE AND MATHEMATICS

Institution	Mathematics		Science	
	Content	Methods	Content	Methods
Appalachian	1	1	1	1
Atlantic Christian	2	1	2	1
Barber-Scotia	2	1	2	1
Campbell		1		1
Catawba	2	½	2	½
East Carolina	2	1	2	1
Elizabeth City State	1		1	
	With a third required course to be either math or science			
Elon	2	¼	3	¼
Fayetteville State	2	½	2	½
Gardner-Webb	1	½	2	½
Greensboro College	2			
	+ one math content elective			
Guilford College	Information not Available			
High Point	2		2	
	+ an additional two courses in math and/or science			
Johnson C. Smith	2	1	2	1
Lenoir-Rhyne	2		2	
Livingstone	2	1	2	1
Mars Hill	3	1	2	
Meredith	1	1	2	1
Methodist College	4		4	1
N. C. Central	3 courses between content and methods		3	
N. C. Wesleyan	2		2	1
Pembroke	1		3	
Pfeiffer	2	½	3	½
Sacred Heart	4		2	
	+ one additional course in math or science			
St Andrews	1			
St. Augustine's	2		2	
Salem	1	1	1	1
Shaw	4	1	2	
UNC-Asheville	1	½	2	½
UNC-Chapel Hill	2		2	
UNC-Charlotte	2	2	2	
UNC-Greensboro	2	½	2	½
UNC-Wilmington	2	1	2	½
Wake Forest University	2		2	
Warren-Wilson	2	½	1	½
Western Carolina	1			1
	+ 2 courses selected from natural sciences and/or math			
Wingate	1	1	1	1
Winston-Salem State	2	1	4	1

Only Elon and N.C. Central University require at least one course in the 3 science certification areas.

FIGURE 3



ELEMENTARY TEACHERS' PERCEPTIONS OF THEIR QUALIFICATIONS TO TEACH MATHEMATICS, SCIENCE, SOCIAL STUDIES, AND READING

Source: Weiss, Iris R., 1977 National Survey of Science, Mathematics and Social Studies Education, Center for Educational Research and Evaluation, Research Triangle Institute, North Carolina

- That each college or university offering Primary and/or Intermediate Certification evaluate the coursework offered in science and mathematics and, where necessary, develop content and methods courses specifically to meet the needs of elementary teachers in these subjects.

Given the fact that most elementary teachers who will be serving the state's students in the coming decade are already in the system, it is essential that in-service training also be provided. This training should provide elementary teachers with training in both content and methods in science and mathematics and should be conducted also to produce positive attitudes toward these subjects among the state's elementary teachers. It is therefore recommended:

- That the state provide funding for permanent summer institute programs in elementary science and mathematics education at selected sites in colleges and universities to upgrade the qualifications of elementary principals, teachers and aides in the subjects of science and mathematics.

Because the demands placed on elementary school teachers in self-contained classrooms are exceptional, there is also a need for on-going assistance by specially trained resource teachers in both science and mathematics. These teachers would provide inservice programs and demonstration lessons, prepare instructional materials, work with elementary science and math projects and contests, conduct programs for aides, volunteers and parents, team teach with interested teachers, and provide special remedial programs where needed in every school in the state. Therefore, the Task Force also recommends:

- That the Department of Public Instruction create new Elementary Math Specialist and Elementary Science Specialist Certificates requiring special training for their resource roles in grades 4-6;

- That these teachers be hired by local option and be selected on the basis of at least 3 years experience, outstanding performance, and commitment of their principal to make effective use of them in this resource role;

- That the state provide a $5000 per year salary supplement to local school systems hiring these resource teachers, to be allocated on the basis of one resource teacher for every 300 students. The state investment would exceed $12 million per year, with local investments totalling more than $40 million per year;

- That these resource teachers be hired for the 1984-85 school year and be required to earn the new specialist certificate by the end of 1986-87 school year;

- That these resource teachers be hired on an 11- or 12-month contract, at local discretion.

Curriculum. The Science Curriculum Study Committee and the Mathematics Curriculum Study Committee of the Department of Public Instruction have recently adopted and published their recommendations for improving the curricula for these subjects in North Carolina. Their recommendations emphasize the need for higher order thinking skills, problem solving, and a hands-on approach to science and mathematics instruction. We strongly endorse their recommendations for implementation in North Carolina at the earliest possible date.

Time. Recent research has demonstrated that the amount of time students spend actively engaged in academic learning tasks is a powerful predictor of student achievement. While this relationship may seem self-evident, further research has shown that we face significant challenges in the allocation and efficient use of time for learning in public schools. This is a particular problem in elementary science and mathematics. In a national study, teachers reported spending an average of 30 minutes per day on science and 44 minutes per day on mathematics. As one observer has noted, "in a week's time of 25 instructional hours, children will have had one hour of science and somewhat less than four hours of mathematics." Furthermore, it is clear that only a fraction of this reported time is actually spent on active learning tasks by students.

There are a variety of causes for this problem, including the low priority assigned to these subjects by elementary teachers, lack of student persistence in academic tasks, and non-academic interruptions in the school day. Given these data it is no wonder that student performance falls below what we would reasonably expect them to achieve.

The Mathematics Curriculum Study Committee has recommended that

> "each (elementary) child have sixty (60) minutes of math daily, with a balance between direct instruction, applications, use of manipulatives, maintenance of skills, and enrichment."

- The Task Force strongly endorses the adoption of this recommendation by the State Board of Education and its implementation by local school systems in North Carolina.

- In addition, the Task Force further recommends that each elementary student have an average of thirty (30) minutes of science instruction daily, including the use of manipulatives and an active, hands-on laboratory program.

- Both of these objectives may best be accomplished by integrating elementary curricula. Thus, science and mathematics can be effectively taught in conjunction with reading, language arts, creative writing, social studies, etc. Elementary curricula should emphasize this interdisciplinary approach.

Materials and Facilities. With the demise of the federal science and mathematics education programs of the 1960s and 1970s, instructional support for science and mathematics has declined significantly. In her 1977 study, Dr. Iris Weiss of the Reserach Triangle Institute found that "insufficient funds for purchasing equipment and supplies and the lack of materials for individualizing instruction are serious problems affecting K-12 science [and] mathematics...instruction." The absence of appropriate materials and facilities leads to an overdependence on the textbook and paper and pencil methods of teaching.

The Governor's Task Force on Science and Technology has conducted a survey of 210 randomly-selected elementary schools in North Carolina to determine the status and needs of science and mathematics instructional resources, including manipulatives, lab equipment and facilities, calculators and computers. Our recommendations, based on the technical report of that survey, are contained in Chapter Four of this report.

Feedback and Accountability. Reliable, valid feedback on pupil performance is a key component of any effective instructional program. It permits teachers to tailor instruction to particular student's strengths and weaknesses and to identify at an early stage those students requiring additional attention, different instructional methods and effective remediation. Similarly, performance measures at the school, district, and state levels greatly assist the identification and development of more effective programs and policies. Much research and our own experience in North Carolina with the Annual Testing Program have demonstrated the value of valid, reliable measures of student performance in language arts and arithmetic. There is some concern, however, that areas not tested in these programs, such as science and higher-order mathematical skills, may actually receive diminished attention as a result of attempts to improve the test scores in other subjects. To restore the curriculum and instructional balance needed to prepare students for a changing technological future and to provide better instruction in science and mathematics, we recommend:

- That the State Board of Education add science to the Annual Testing Program at grades 3 and 6, as well as grades 9 and 12, and further ensure that the content of the mathematics tests include thinking skills beyond mere factual recall, such as problem solving, analysis, and synthesis. Costs for administering the tests would equal about $300,000 annually, with an additional one-time development cost of $150,000 during the first year.

Summary

Solving our problems in science and mathematics education will require particular attention to the quality of elementary instruction in these subjects. We have recommended steps for improving elementary science and mathematics education, including:

- Developing committed, informed leadership among elementary school principals.
- Strengthening primary (K-3) and intermediate (4-6) certification requirements in science and math.
- Providing summer institutes in science and math for elementary teachers.
- Providing specially trained and compensated science and mathematics resource teachers in every LEA.
- Full and rapid implementation of the curriculum recommendations of the Mathematics and Science Curriculum Study Projects.

- Provision of adequate time for instruction in science and mathematics.

- Strengthening the Annual Testing Program by including science at grades 3, 6, 9 and 12, and by including higher order mathematical skills.

A number of actions are both underway and proposed for strengthening science and mathematics instruction at the secondary level. The success of all of those initiatives is likely to hinge on providing successful experiences in science and mathematics at the elementary school. We believe that the implementation of this set of proposals will ensure our success in North Carolina.

Chapter Four

CURRICULUM AND INSTRUCTIONAL RESOURCES

In addition to excellent teachers and a high level of pupil participation, excellence in science and mathematics education requires a strong, appropriate curriculum and the instructional resources necessary for outstanding learning. Here again, as recent national and state-wide reports have indicated, a major improvement effort is needed.

Curriculum

Over the past several years, national studies and reports have documented the need for renewed attention to science and mathematics curricula. Problems which have been highlighted include:

- Decline of Federal Support. Through the National Science Foundation, the federal government invested nearly $1 billion in the development and support of science and mathematics curricula during the period of the 1960s and early 1970s. However, the decline of these programs has led to virtually no federal leadership or investment in curriculum development and support in recent years.

- Inappropriate Curriculum. Many have expressed concerns that current science and mathematics curricula are uninteresting and inappropriate for the majority of public school students, most of whom will not become scientists and engineers.

- Scientific Literacy. Scientific literacy and societal issues involving technology are inadequately addressed in most curricula. In addition, little integration of science and mathematics curricula with humanities, social sciences and language arts has been attempted.

- Overdependence on Textbook. Science and mathematics teachers depend almost exclusively on textbooks for defining and directing the curricula in their classrooms. Other curricular resources and media are largely untapped. Though many have given lip-service to the value of active, "hands-on" learning and inquiry-based instruction, little of either appears to be common in science and mathematics classrooms.

- No Method for Updating Curriculum. While science and technology have advanced rapidly in the last two decades, science and mathematics curricula have changed little. As the demands of technological advance change over time, the skills and knowledge incorporated in science and mathematics courses will need to be up-dated. No mechanism for this on-going curriculum improvement exists.

- Teacher Experience Ignored. Teachers have frequently been left out of the curriculum development process. This has clearly led to less effective design and implementation of curricula in science and mathematics.

- Lack of Curriculum Support. Support mechanisms for science and mathematics curricula -- primarily teacher training through NSF summer institutes -- no longer exist.

In North Carolina, extensive studies of science and mathematics curricula were recently completed. The reports of the Science Curriculum Study Committee and the Mathematics Curriculum Study Committee of the State Board of Education provide a blueprint for upgrading the curriculum in these subjects. In summary, these reports call for:

- The development and implementation of curricula in science and mathematics which are appropriate to a broad range of students, which incorporate basic skills necessary for employment and training in a technology-based economy, and which provide a high level of scientific literacy for all students graduating from North Carolina's public schools;

- stronger emphasis on problem solving, critical thinking, and "learning to learn" skills;

- use of an active, hands-on approach to instruction in science and mathematics;

- higher expectations for student performance in science and mathematics; and

- clearer coordination and articulation of science and mathematics curricula between elementary schools, junior high/middle schools, and high schools.

The Governor's Task Force on Science and Technology strongly endorses the goals and recommendations of the Curriculum Study Committees in science and mathematics.

In addition to the recommendations of the curriculum study committees, there is a need to fill the gap left by the decline of federal leadership in science and mathematics. An effective mechanism for curriculum development at the state level should be closely tied to teacher education to ensure effective use of the curriculum in classrooms across the state. In addition, development of new curricula in science and mathematics should involve broad participation from teachers, scientists, mathematicians, science and mathematics education specialists and professors, educational researchers, employers of technical workers and professionals, and specialists in the humanities and social sciences. The Task Force therefore recommends:

- That science and mathematics curriculum development projects be funded and initiated through the developing network of Centers for Science and Mathematics at colleges and universities across the state. Each project should be tied to teacher education at the centers and involve a broad spectrum of participants, including teachers, in upgrading curricula for scientific literacy, for broad student interest, and for developing skills critical to success in a technological society.

Instructional Resources

While this report and others have focused on increasing the supply and quality of teachers in science and mathematics, it is important to recognize that the most immediate improvements in science and mathematics instruction in North Carolina will be realized by providing adequate resources for instruction to every classroom. These resources -- equipment, materials, time, computers, etc. -- are particularly important for effective, hands-on training in science and mathematics. Again, however, declining federal support, increasingly strained school budgets, and rising costs have created a significant gap which must be filled through state and local action.

To assess the current needs for instructional support in science and mathematics, the Governor's Task Force on Science and Technology conducted a comprehensive survey of science and mathematics department chairpersons in every secondary school in the state and principals from a random sample of 210 elementary schools.[1] The results of this survey should give direction to the state's efforts to improve instruction in science and mathematics. A summary of key findings from this survey points to the need for effective state and local action to provide adequate instruction resources.

Equipment and Materials. An effective laboratory program in science requires specialized equipment and supplies, both consumable and non-consumable. However, budget constraints have prevented many public schools from purchasing these items, frequently debilitating their science programs. One-third of the high schools and over 44 percent of the junior high schools were unable to spend any money on science equipment during the 1982-83 school year. At the high school level equipment, consumable supplies, and non-consumable supplies were ranked as the top three priorities for funding to improve instruction. Similarly, at the junior high level consumable supplies and equipment were the top two priorities in science. At the elementary level, principals ranked the need for supplies and materials second in importance only to increased teacher training in science and mathematics. If teachers are to be expected to give outstanding instruction in science and mathematics, they must be given the tools with which to teach. Clearly, these tools -- instructional equipment and supplies -- are not available for many teachers.

In addition, effectively introducing new equipment and resources into classrooms will require more than just money. Careful planning by both principals and teachers as well as training and assistance in the operation and maintenance of new equipment is also necessary. No effective mechanisms for this type of assistance now exist in North Carolina.

Computers and Calculators. While it is widely recognized that skills in using computers and calculators are becoming basic in our information society, survey data indicate North Carolina public schools have been slow to respond to using these technologies in public schools:

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[1] A Survey of K-12 Science and Mathematics Education Needs in North Carolina, Spring 1983. N.C. Board of Science and Technology, (In Press, Fall 1983).

TABLE 8

MEAN NUMBER OF MICROCOMPUTERS PER SCHOOL

School Level	U.S.*	North Carolina+
Senior High School	10.4	6.2
Junior High School	7.2	2.6
Elemetary School	4.3	not available

* Source: Educating Americans for the 21st Century. National Science Board Commission on Precollege Education in Mathematics, Science and Technology, September, 1983.

+ Source: A Survey of K-12 Science and Mathematics Needs in North Carolina, Spring 1982. N.C. Board of Science and Technology, (In Press, Fall 1983)

- 56 percent of North Carolina's high schools have fewer than six microcomputers.
- 75 percent of North Carolina's junior high schools have fewer than four microcomputers.
- 71 percent of the high schools and 76 percent of the junior high schools reporting using no computers for science instruction.
- 45 percent of the high schools and 49 percent of the junior high schools reported using no computers for mathematics instruction.
- 45.5 percent of North Carolina's elementary schools have no microcomputers; less than 10 percent have more than three microcomputers.
- 34 percent of the junior high schools and 66 percent of the high schools report using calculators in mathematics classes.

These data indicate the need for statewide provisions for the acquisition of computer hardware. In addition, there is a pressing need for systematic training of teachers, development of courseware, and integration of computers and other new technologies into school curricula. In particular, science and mathematics courses should capitalize on the strengths of computer simulations, computer-assisted instruction, and computer-managed instruction. A major thrust in computer education is essential if North Carolina is to continue to compete nationally for high skill, new technology industry.

Time and Class Size. At every level, a need for increased time for instruction in science and mathematics exists. This need results from a variety of problems, including unnecessary interruptions of classes, student absenteeism, early dismissals for student athletes and others, conflict between curricular and extra-curricular activities, etc. In addition, laboratory-based courses require additional time for lab set-up, experiments, and clean-up -- a fact often overlooked by school schedules. It seems clear that in many schools the time currently allocated for instruction could be used more efficiently, given strong leadership by the principal. In addition, extending the time for instruction in the core academic subjects could be accomplished by narrowing the course selection and scheduling more "double-periods" in these subjects. Finally, experiments in extended school days and extended school years should be carefully evaluated for their effectiveness in providing better learning through increased instructional time.

In addition to increased time for instruction, teachers at every level ranked reducing class size as an important priority for improvement. In spite of the lack of data supporting a direct relationship between marginal reductions in class size and student achievement, teachers continue to perceive class size as an important obstacle to improved instruction. This concern may be related to the question of the time available for direct individualized instruction, the ability of the teacher to prepare for instruction adequately, and the difficulty in maintaining an effective academic atmosphere in large classes. In addition, large class sizes appear to be a hindrance to laboratory instruction. Since most laboratories have been built for class sizes of 24 or less, large classes are not only difficult to teach in such facilities, but can be quite dangerous during laboratory activities. Many teachers refuse to teach large laboratories because of the safety hazards, and resort to less stimulating instructional methods.

Permanent Resource Structures. The experience of the past two decades, during which federal support for science and mathematics has all but disappeared, has made it clear that a temporary "shot in the arm" for science and mathematics is of limited value. What is needed is permanent, dependable support for science and mathematics education from the state and local levels. This support should include funding for equipment and materials, support for computer education, technical assistance in the use of new equipment and materials, repair of equipment, and sharing of high cost resources among schools and systems. Resource centers for science education already exist in the Greenville and Asheville areas. These models could be further developed and reproduced in other areas of the state to great benefit. With a solid base of support from the state and local school systems, they could also attract and effectively use federal and private funds.

Recommendations. To provide the instructional resources necessary for effective instruction in science and mathematics, the Task Force recommends:

o That the General Assembly provide funding earmarked for science and mathematics laboratory equipment and instructional materials in grades K-12. Funds should be appropriated on the basis of enrollments in science and mathematics courses in secondary schools and on the basis of school membership in elementary schools. Each local school system receiving these funds should be required to develop and annually update a master plan for improving science and mathematics instruction in their schools. Based on our survey of needs across the state, we recommend the following funding levels per year:

	Approximate Cost
\$10 per pupil enrolled in SCIENCE, grades 9-12	\$ 2.2 mil.
\$ 7 per pupil enrolled in SCIENCE, grades 7-8	\$ 1.3 mil.
\$ 4 per pupil enrolled in MATH, grades 9-12	\$ 1.0 mil.
\$ 4 per pupil enrolled in MATH, grades 7-8	\$ 0.7 mil.
\$ 3.50 per pupil, grades K-6	\$ 2.0 mil.
Approximate Total Cost =	\$ 7.2 mil.

- That the General Assembly establish and appropriate \$1.5 million per year for a N.C. Microcomputer Education Fund. Under the direction of the State Board of Education, this fund would be used to support the acquisition of computer hardware, software and training by local school systems through matching state and local funds; to fund the development of effective course curricula and teacher training in microcomputers; to establish and support a computer software clearinghouse for public schools in North Carolina; and to support model projects in innovative uses of microcomputers in education.

- That the State Board of Education, beginning in 1986-87, require local school systems to restrict the size of all secondary science classes to 24 students, and to adopt flexible class scheduling which permits double-periods for laboratory classes in science.

- That superintendents, principals, department chairs and other instructional leaders develop strategies to maximize the amount of instructional time in their classrooms and schools, especially in science and mathematics.

- That the General Assembly, in conjunction with the Department of Public Instruction and UNC, establish Science and Mathematics Resources Cooperatives in association with the Science and Mathematics Centers now being developed. These resource cooperatives should provide technical assistance to local schools to develop a master plan for improving instruction in science and mathematics, equipment and media sharing, equipment repair, and teacher training in the use of instructional resources, including new technologies and microcomputers.

Chapter Five

RESPONDING TO THE CHALLENGE OF CHANGE: THE UNDERLYING ISSUES

Underlying all of the issues addressed in this report are two more fundamental challenges which our schools must address in the face of rapid technological change. One is the the need to foster educational innovation to adapt to new demands. The other is the need to rebuild public consensus on the goals of educational improvement and commitment.

Educational Innovation

The new demands created by technological development are affecting virtually all of the institutions in our society. Business and industrial corporations are faced with a mandate to adapt to and harness new technologies or lose their ability to produce and compete in the world marketplace. Government must develop new institutions and restructure old ones to harness science and technology for the benefit of all citizens.

Similarly, schools must find ways to respond to the demands of technological development. As the skills needed for success in modern society grow and change, schools will be faced with new expectations and new priorities. Responding to these will necessitate both new programs and significant changes in those programs that now exist. The scope of the changes required will be broad -- curriculum, personnel, professional training, leadership, resources, even the mission and organization of schools will be affected.

In this respect, there is little difference between the schools and business and industry. Both the challenges and the problems encountered in adapting to change are similar. Business and industry, for instance, have struggled to maintain vigorous research and development programs in recent years. Frequently the long-term benefits of innovative investments have been subverted to the short-term payoffs of limited risks. Yet, it is clear that a healthy commitment to research and development is essential if we are to develop the new processes and products which will keep our economy productive, competitive and vigorous.

There is a similar need for investment in research and development in education. Recent research has confirmed what many educators have long known -- it is extremely difficult to develop and sustain innovation in public schools. Schools have remained strikingly unchanged through the years. There are a variety of cultural, historical, and institutional causes for this. An immediate one is the lack of funding for research and development leading to innovation in public schools.

Much of the share of funding research and innovation in education over the past 25 years has been borne by the federal government. However, sharp declines in federal spending in education have largely removed federal agencies from this role. For example, National Science Foundation support for science and engineering education has declined steadily for some 22 years, from a high of 47 percent of their total budget in 1959 to a 1982 low of 2 percent. Similarly, the Elementary and Secondary Education Act (ESEA) Title

IV-C program, which funds innovative programs in local schools, has been drastically reduced; North Carolina's share dropped from over $2.5 million in 1980-81 to barely $400,000 in 1982-83.

In 1982-83, North Carolina spent approximately $2.5 million on research and development in education (Table 9). This is less than 0.2 percent of the total budget of the State Department of Public Instruction. No major corporation could long survive with that level of investment in research and development. Furthermore, with the decline of federal support, most of the state funds will support only simple assessment programs such as the Annual Testing Program. Little, if any, of even this small allocation will contribute to innovation in school programs.

There is a clear need, then, for significantly increased funding for research and development of innovative programs in schools. The mechanism of funding should:

- Assure adequate support of basic educational research.
- Assure adequate support for applied research and development of new educational methods and technologies.
- Support locally-based innovations for school improvement, and assure the maximum leverage of state dollars on other funding sources for this project.

To accomplish the above, we recommend:

- That the federal government restore and significantly expand its support for educational research and development, local innovation, curriculum development, and media production.
- That the General Assembly establish a N.C. Foundation for R&D in Education and provide support of $1,500,000 per year to be supplemented by private sector, foundation, and other sources. This foundation, governed by a board of educators, government leaders, higher educators, and lay citizens, should promote local innovation in schools, basic and applied educational research, development of new educational technologies, educational policy research, and long-range educational planning through competitive grants and program sponsorship.
- That local communities develop mechanisms to draw on local resources for innovative school improvement projects. These may include local education foundations, cultivating program support from local civic groups, professional societies, chambers of commerce and businesses, and budgeting development funds from local tax revenues.

North Carolina School of Science and Mathematics

The N.C. School of Science and Mathematics is a residential school for 11th and 12th grade students with very high aptitude in science and mathematics. Established in 1979, the School has two major goals: (1) to train and inspire students in residence to become, with further education and experi-

TABLE 9

SUPPORT OF R&D IN THE DEPARTMENT OF PUBLIC EDUCATION BY SOURCE OF FUNDS

Year	Division of Research	Development (ESEA IV-C)	Division of School Planning	Total
		(thousands of dollars)		
1981 (Actual)				
State	1954.4	67.4	410.0	2431.8
Federal	80.0	2506.0	--	2586.0
Other	--	37.6	--	37.6
1982 (Budget)				
State	1766.3	70.6	652.3	2489.2
Federal	117.5	2176.4	--	2293.9
Other	--	--	--	--
1983 (Budget Estimate)				
State	1866.2	--	684.3	2550.5
Federal	152.4	403.0	--	555.4
Other	--	--	--	--
1984 (Budget Recommendation)				
State	2170.0	--	685.0	2855.0
Federal	150.0	--	--	150.0
Other	--	--	--	--
1985 Budget Recommendation				
State	2170.0	--	685.0	2855.0
Federal	150.0	--	--	150.0
Other	--	--	--	--

ence, leading scientists, engineers and mathematicians of tomorrow; and (2) to help foster, through its outreach program, significant improvements in education in science and mathematics in all elementary and secondary schools of the state.

The School is to remain small; the maximum number of students in residence is not to exceed 900. In September, 1983, nearly 400 students were enrolled. Outreach programs include summer short courses in science and mathematics for teachers from other secondary schools in North Carolina, internships for teachers from other schools; special conferences and workshops for students, teachers, administrators, school boards, and others from across the state; and other measures.

The Task Force did not examine the School in detail, nor did it seek to develop specific recommendations for the School in relation to its other recommendations. The Board of Trustees of the School includes the Chairman of the State Board of Education, the State Superintendent of Public Instruction, and representatives from higher education, secondary schools in North Carolina, and other constituencies. Working with the constituencies represented on the Board of Trustees, the School develops and executes plans in accordance with its goals. The intent is for the School to become an integral part of the total education system of North Carolina. It is an innovative institution itself and expects to contribute significantly to the North Carolina response to the challenges of the current technological age. The N.C. Foundation for Research and Development in Education, recommended above, would be expected to study the experience of the School and derive information useful to other schools throughout the state.

Creating Consensus

Each of the four issue areas discussed in this report -- teacher supply and quality, pupil enrollment and performance, curriculum and instructional resources, and innovation in schools -- presents significant challenges requiring major changes and investments in our educational system. However, a more fundamental challenge underlies these problems and is at the heart of many of the difficulties in public education. This problem, as discussed in Chapter One, is the loss of public confidence in our schools, the lack of consensus on our goals for school improvement and therefore our lack of commitment to seeing these improvements through. If we fail to address this fundamental problem, all other action we take will be of limited and temporary benefit.

We must rebuild the public consensus on the aims and role of education and commitment to make the tough choices and investments to assure educational excellence in North Carolina.

Accomplishing this task will involve creating a sense of shared ownership of schools by the entire community, focusing on ambitious but achievable goals for school improvement, and building a track record of success in these efforts. Confidence will be developed in the context of successful actions and programs for school improvement. The strategy we adopt must focus on public involvement in local school improvement efforts, with support from the state.

A number of examples of this strategy already exist. Local improvement efforts in science and mathematics education are now underway with no state financial support in Charlotte-Region VI, Greenville-Pitt County, Greensboro-High Point, the Wilmington area, the Roanoke Rapids area and elsewhere. The key elements of these successful programs are:

a) The formation of a planning and resource team composed of educators, business leaders, and other community leaders to plan programs for school improvement,

b) A focus on specific, achievable objectives,

c) Using, to a large extent, local resources to solve local problems in these areas of instruction,

d) A focus on action rather than unresolvable issues.

Based on these experiences, a combination of foundation and state funds was recently made available as seed money for eight additional Local Model Partnership Programs in science and mathematics. These programs should have significant impact on local science and mathematics programs and help rebuild the public confidence and commitment to excellence in their local schools. This change in attitudes should translate into the political commitment to make the difficult changes and sustain the investments necessary to improve public education.

To extend this successful strategy, we recommend:

- Every school system and local community should develop a local task group composed of leaders from education, business, government, civic and community groups to a) assess the status and needs of science and mathematics education in their local schools, b) map out a strategy for improving these programs, and c) implement their plans with whatever resources can be brought to bear from the local community, the state, and other sources.

- The state, through the Governor's Business Committee on Science and Mathematics Education or other avenues, should encourage the creation of a private education foundation. Funds for its creation would be drawn from private industry, and would be used to support in-service training for teachers, science fairs, and other similar programs.

- The state's community and technical colleges should work with local secondary schools to make efficient use of the latters' facilities for adult education and training courses during the evening and on weekends.

- The state should expand the Local Model Partnership Program to include an additional 16 projects in science and 16 projects in mathematics.

- That the lessons learned and programs developed in the local improvement programs be communicated to systems throughout the state and to decision makers at the state level.